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Wildfire and Prescribed Fire Scenarios in the Columbia River Basin Relationship to Particulate Matter and Visibility

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INTRODUCTION

Increases of prescribed fire activity appear in a majority of the alternatives within the Eastside and Upper Columbia Environmental Impact Statements. The CRBSUM model can be used to determine approximations of total smoke outputs associated with wildfire and prescribed fire for the alternatives but this is based upon a yearly or series of yearly totals. The problem with this system is that wildfires and prescribed fires do not occur evenly spaced throughout the year, but rather occur in a pattern more likely defined as episodes.

For wildfires a combination of weather conditions and ignition sources (usually lightning) need to occur. When weather associated with intense fire behavior and multiple ignitions occurs the result can be multiple large fires. These large fires result in the majority of all acres burned due to wildfire.

In the case of prescribed fire, weather is a primary factor in determining if an area can be burned under conditions that will meet the objectives of this management activity. When the weather conditions become favorable for prescribed fire the area affected is usually large resulting in episodes when large amounts of prescribed fire is occurring.

The CRBSUM model is not responsive to these episodes of fire activity either wildfire or prescribed. To more realistically model the impacts of smoke production from these episodes of high activity a different modeling scheme was developed. This scheme considered the impact of various levels of wildfire and prescribed fire activity on National Ambient Air Quality Standards for particulate matter (PM_{10} and $PM_{2.5}$) and Air Quality Related Value (AQRV) of visibility on a "regional" scale, across the entire project area.

With assistance from the U.S. Environmental Protection Agency (EPA) to supply weather data (MM4 data for 1990) and aid in the modeling concept the U.S. Forest Service, Portland, OR let a contract to Earth Tech of Concord, MA, utilizing CALPUFF non-steady-state dispersion model (Scire et al., 1995a). The Forest Service supplied the data for smoke emission factors and the scenario designs of acres burned by vegetation type.

METHODS

Scenario Development - Wildfire

To obtain a realistic estimate of spatial placement, size, and acres burned per day for wildfires daily records kept at Northwest Coordination Center were used (records used were ICS-209 forms and daily situation reports). Only those wildfires 100 acres and larger were used in this analysis because of the availability of the data was more consistent and available for fires of this size and also these the few larger fires make up the vast majority of the wildfire acres burned. The origin of the fire was used to place the fire for modeling purposes. An eight day period was used to track how many acres burned per day for an estimate of cumulative impacts of emissions. Eight days were selected to fit the analysis within budget. Weather data from the MM4 model for

August 6th through the 13th were used to modeling all wildfire scenarios. This time period was used because it represented a weather scenario when wildfires took place in the project area in 1990, the year of the weather data set.

Wildfire scenarios were selected from actual 8 day events that took place. There were three wildfire episodes modeled – August 6-13, 1990, July 27-August 3, 1994, and August 20-27, 1994. All three of these scenarios represented an active wildfire scenario with over 150,000 acres burned in the 8 days. To make an estimate of emissions for wildfire scenarios that weren't so active (i.e., fewer acres burned during an 8 day period), each of the 3 wildfire scenarios listed above were reduced by 50 percent and 25 percent of acres burned during the eight days (See Table 1). To bring the 1990 scenario below 200,000 acres and provide some variability between the data sets one fire, Pine Springs Basin which burned 65,000 acres during this period was dropped from modeling. This fire was arbitrarily selected because it was large and only one fire needed to be dropped from the data to provide a significant departure from the other to wildfire scenarios which were dropped from the data set to provide a significant departure from the other two scenarios which were both well over 200,000 acres.

Wildfire included in this analysis included all agency fires (State and Federal).

Table 1 – Modeled Acres Burned Per Day by Wildfire

Scenarios	# of Fires	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Total
Aug 6-13, 1990	34	2,650	4,346	26,055	25,754	78,763	21,922	7,021	4,669	171,180
50% of Aug 6-13	34	925	2,173	13,028	12,877	39,382	10,961	3,511	2,335	85,192
25% of Aug 6-13	34	463	1,087	6,514	6,439	19,691	5,481	1,755	1,167	42,595
July 27-Aug 3, 1994	45	36,455	37,282	83,256	47,518	22,061	29,795	11,956	5,082	273,405
50% of July 27-Aug 3	45	18,288	18,641	41,628	23,756	11,129	14,898	5,978	2,541	136,799
25% of July 27-Aug 3	45	9,144	9,321	20,814	11,880	5,515	7,449	2,989	1,271	68,351
Aug 20-27, 1994	34	38,989	34,218	26,699	35,310	31,381	21,205	19,211	31,821	238,834
50% of Aug 20-27	34	19,495	17,109	13,350	17,655	15,691	10,603	9,606	15,911	119,420
25% of Aug 20-27	34	9,747	8,555	6,675	8,828	7,845	5,301	4,803	7,955	59,709

Scenario Development - Prescribed Fires

To make an estimate of a baseline that matched the weather that was available for modeling (the 1990 MM4 weather data set), a count of all the prescribed fires in 1990 from all federal agencies in the project area was obtained. Unfortunately not all agencies kept the locations of the prescribed fires in latitude and longitude coordinates and in some cases is missing entirely. However, work done by Janice Peterson in 1989 provided an insight on what proportion of prescribed fires were done by vegetation types (see Table 2). Each prescribed fire reported was coded as to the type of burn, e.g. pile, underburn, or broadcast. Since we didn't have good locations for these prescribed fires, but we did have a reasonable idea of what vegetation type they burn in, by using Peterson's 1989 data, the prescribed fires were spatially placed by randomly

August 8" during the 17th" were used to meteling at [illegible] stations. This time period was [illegible] because it represents the [illegible] season when [illegible] work place in the project area in 1970, the year of the [illegible].

Wildlife scaring was [illegible] on [illegible] 8 day events that took place. There were three wildlife episodes [illegible] – August 8-12, 1970; July [illegible]; [illegible] and August 20-22, 1970. After the [illegible] scaring [illegible] as active wildlife [illegible] with [illegible] burned in the 8 day. The [illegible] or [illegible] for wildlife [illegible] that [illegible] active fire [illegible] burned during the 8 day period, [illegible] wildlife [illegible] above were reduced by 50 percent or [illegible] percent of acres burned during the eight day [illegible] Table 1). Therefore, the 1970 [illegible] below 70,000 acres and provide same [illegible] the data [illegible] Bunchgrass burned 65,000 acres during this period was [illegible] from a [illegible]. This fire was [illegible] selected because it was far [illegible] one [illegible] [illegible] from the [illegible] provide [illegible] from the [illegible] to wildfire [illegible] [illegible] to the [illegible] provide a [illegible] [illegible] the other [illegible] acres [illegible] 300,000 acres.

While [illegible] in this analysis include [illegible] Fire Chiefs and Foreman.

Table 1 – Bunchgrass [illegible] acreage by [illegible]

Scenario	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Total
	(acres)								
August 13, 1970	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
August 20, 1970	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
August 20, 1970	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Scenario Descriptions - Prescribed Fires

To [illegible] analysis, information on the prescribed fires was available for [illegible] the 1970 August 8 wildfire [illegible] of the prescribed fires in 1970 from all [illegible] agencies in the region was unknown. [illegible] of agencies kept the locations of the prescribed fires in [illegible] and magnitude [illegible] and in some cases [illegible] existing records). [illegible] provided an insight on [illegible] proportions of prescribed fires were [illegible] (Table 2). Each [illegible] the proposed [illegible] coded as to type of burn, [illegible] on [illegible]. Some [illegible] have [illegible] [illegible] at what [illegible] the [illegible] by using [illegible] 3 days. The prescribed fires were spatially placed by randomly

selecting locations by vegetation type. Each vegetation type was then allocated a number of prescribed fires by their proportion to the total.

Table 2 – Percentage of Prescribed Fires by Vegetation Type		
Vegetation Type	Spring Prescribed Fire % by Vegetation Type	Fall Prescribed Fire % by Vegetation Type
Grass	13	1
Shrub	19	8
Ponderosa Pine	5	7
Mixed Conifer	62	84

Tables 3a through 3h show how many prescribed fires units, unit sizes, and total acres burned by vegetation type for Spring for each management scenario modeled.

Table 3a– Baseline for Prescribed Fires Spring Scenarios					
Veg Type	% of Total Rx Fire units	Burn Type	Average Unit Size	Number of units	Acres
Grass	11.5	Underburn	20	9	182
Shrub	14.4	Underburn	21	11	229
Ponderosa Pine	6.8	Broadcast	22	5	108
	3.2	Pile	17	3	50
Mixed Conifer	1.6	Underburn	26	1	26
	20.4	Pile	13	25	323
	42.1	Broadcast	32	21	668
Totals	100%		21	75	1,586

acres lost to land by vegetation type. Each vegetation type was then allocated a number of prevented fires by Rich, proportional to the total.

Table 1 – Percentage of Prevented Fires by Vegetation Type		
Veg Type	Burning Prescribed Fire % by Vegetation Type	Fail Prescribed Fire % by Veg Type
Grass	[illegible]	[illegible]
Scrub	[illegible]	[illegible]
Pandanus Palm	[illegible]	[illegible]
Mixed Woodland	[illegible]	[illegible]

Tables 2a through 2e show how many prescribed fire units, grass, scrub, and total acres lost to vegetation type for burning for each burning season scenario modeled.

Table 2a – Burning for Prescribed Fire Only Burning Scenarios				
Veg Type	Acres Lost to Total Fire Units	Burn Units	Average Lost Acres	Number of Units Avoided
Grass	[illegible]	[illegible]	[illegible]	[illegible]
Scrub	[illegible]	[illegible]	[illegible]	[illegible]
Pandanus Palm	[illegible]	[illegible]	[illegible]	[illegible]
Mixed Woodland	[illegible]	[illegible]	[illegible]	[illegible]
Total	[illegible]	[illegible]	[illegible]	[illegible]

Table 3b – Baseline + 100% for Prescribed Fires Spring Scenarios					
Veg Type	% of Total Rx Fire Acres	Burn Type	Average Unit Size	Number of units	Acres
Shrub	10	Underburn	100	3	317
	6	Underburn	200	1	190
	4	Underburn	500	0	127
Ponderosa Pine	20	Underburn	30	21	634
	12	Underburn	100	34	381
	8	Underburn	250	1	254
Mixed Conifer	25	Pile	25	32	793
	15	Broadcast	30	16	476
Totals	100%		41	78	3,172

Table 3c – Baseline + 200% for Prescribed Fires Spring Scenarios					
Veg Type	% of Total Rx Fire Acres	Burn Type	Average Unit Size	Number of units	Acres
Shrub	10	Underburn	100	5	476
	6	Underburn	200	1	285
	4	Underburn	500	0	190
Ponderosa Pine	20	Underburn	30	32	952
	12	Underburn	100	6	571
	8	Underburn	250	2	381
Mixed Conifer	25	Pile	25	48	1,190
	15	Broadcast	30	24	714
Totals	100%		41	117	4,758

Table 3d – Baseline + 300% for Prescribed Fires Spring Scenarios					
Veg Type	% of Total Rx Fire Acres	Burn Type	Average Unit Size	Number of units	Acres
Shrub	10	Underburn	100	6	634
	6	Underburn	200	2	381
	4	Underburn	500	1	254
Ponderosa Pine	20	Underburn	30	42	1,269
	12	Underburn	100	8	761
	8	Underburn	250	2	508
Mixed Conifer	25	Pile	25	63	1,586
	15	Broadcast	30	32	952
Totals	100%		41	156	6,344

Table 3e – Baseline + 500% for Prescribed Fires Spring Scenarios					
Veg Type	% of Total Rx Fire Acres	Burn Type	Average Unit Size	Number of units	Acres
Shrub	12.5	Underburn	250	5	1,190
	7.5	Underburn	500	1	714
	5	Underburn	1000	0	476
Ponderosa Pine	25	Underburn	35	68	2,379
	15	Underburn	150	10	1,429
	10	Underburn	500	2	952
Mixed Conifer	15	Pile	25	57	1,427
	10	Broadcast	30	32	952
Totals	100%		54	175	6,344

Table 41 – Hospitality 2000 for Fire Rated Fire Doors Supplier

Size Type	% of Total Fire Doors	Door Type	Average Unit Size	Number of units	Access
Single	10	Flush door	840	6	42%
	6	Steel door	720	3	28%
	4	Veneer door	900	1	25%
Double Door Pair	30	Underwater	30	4	1,250
	2	Solid wood	100	6	791
	8	Glass door	50	2	50%
Sliding Door	15	Pole	55	63	1,520
	12	Glass door	30	7	0%
Totals	100%		41	138	0.74

Table 36 – Hospitality 2000 for Fire Rated Fire Doors Supplier

Size Type	% of Total Fire Doors	Door Type	Average Unit Size	Number of units	Access
Single	12.5	Underwater	250	5	1,750
	7.5	Solid wood	500	1	71%
	5	Double door	1000	0	45%
Double Door Pair	55	Solid wood	55	22	1,172
	15	Underwater	150	10	1,42%
	10	Glass door	500	2	0%
Sliding Door	15	Pole	25	18	1,42%
	10	Solid door	30	25	0%
Totals	100%		54	125	0.74%

Table 3f – Baseline + 750% for Prescribed Fires Spring Scenarios					
Veg Type	% of Total Rx Fire Acres	Burn Type	Average Unit Size	Number of units	Acres
Shrub	12.5	Underburn	250	7	1,685
	7.5	Underburn	500	2	1,011
	5	Underburn	1000	1	674
Ponderosa Pine	25	Underburn	35	96	3,370
	15	Underburn	150	13	2,022
	10	Underburn	500	3	1,384
Mixed Conifer	15	Pile	25	81	2,022
	10	Broadcast	30	45	1,384
Totals	100%		54	248	13,481

Table 3g – Baseline + 1000% for Prescribed Fires Spring Scenarios					
Veg Type	% of Total Rx Fire Acres	Burn Type	Average Unit Size	Number of units	Acres
Shrub	12.5	Underburn	250	9	2,181
	7.5	Underburn	500	3	1,308
	5	Underburn	1000	1	872
Ponderosa Pine	25	Underburn	35	125	4,362
	15	Underburn	150	17	2,617
	10	Underburn	500	3	1,745
Mixed Conifer	15	Pile	25	105	2,617
	10	Broadcast	30	58	1,745
Totals	100%		54	321	17,446

Table 7b - Baseline + 750% for Proportional Flow System Sensitivity

Vessel Type	% of Total Rx Fees/Year	Burn Type	Average Line Size	Number of Lines	Acres
Sloops	12.5	Underburn	750	7	1,688
	7.5	Underburn	500	3	1,011
	5	Underburn	1000	1	674
Fishermen Pipe	25	Underburn	35	94	2,979
	15	Underburn	150	13	2,023
	10	Underburn	500	3	1,348
Mixed Counter	15	Pile	25	81	2,023
	10	Underburn	50	43	1,349
Total	100%		34	242	13,045

Table 7c - Baseline + 1000% for Proportional Flow System Sensitivity

Vessel Type	% of Total Rx Fees/Year	Burn Type	Average Line Size	Number of Lines	Acres
Sloops	12.5	Underburn	750	8	1,688
	7.5	Underburn	500	3	1,011
	5	Underburn	1000	1	674
Fishermen Pipe	25	Underburn	35	105	2,979
	15	Underburn	150	13	2,023
	10	Underburn	500	3	1,348
Mixed Counter	15	Pile	25	105	2,023
	10	Underburn	50	55	1,349
Total	100%		34	301	13,046

Table 3h – Baseline + 1500% for Prescribed Fires Spring Scenarios					
Veg Type	% of Total Rx Fire Acres	Burn Type	Average Unit Size	Number of units	Acres
Shrub	12.5	Underburn	500	6	3,172
	7.5	Underburn	1000	2	1,903
	5	Underburn	2000	1	1,269
Ponderosa Pine	30	Underburn	70	109	7,613
	18	Underburn	300	15	4,568
	12	Underburn	1000	3	3,045
Mixed Conifer	10	Pile	25	102	2,538
	5	Broadcast	30	42	1,269
Totals	100%		91	280	25,376

Tables 4a through 4h show how many prescribed fires units, unit sizes, and total acres burned by vegetation type for Fall for each management scenario modeled.

Table 4a– Baseline for Prescribed Fires Fall Scenario					
Veg Type	% of Total Rx Fire units	Burn Type	Average Unit Size	Number of units	Acres
Grass	0		0	0	0
Shrub	2.4	Underburn	81	18	1,464
Ponderosa Pine	0.1	Underburn	23	1	23
	11.8	Pile	19	89	1669
	0.5	Broadcast	17	4	70
Mixed Conifer	0.3	Underburn	38	2	76
	79.6	Pile	16	600	9,355
	5.3	Broadcast	31	40	1,226
Totals	100%		18	754	13,883

Table 5b - Baseline + 120% for Prescribed Fires Sign-on Scenarios					
Veg Type	% of Total BA For Acres	Burn Type	Average Unit Size	Number of units	Acres
Shrub	1.2	Underburn	500	6	2,172
	3.5	Underburn	1060	2	1,909
	2	Underburn	4000	1	3,209
Ponderosa Pine	10	Underburn	70	109	7,613
	15	Underburn	300	15	4,595
	12	Underburn	1000	3	3,447
Mixed Conifer	10	Pile	25	102	2,558
	5	Broadcast	30	12	209
Totals	100%		91	280	22,771

Table 6 - 100% High-Sign-on scenarios where only prescribed fires occur, and none, and total acres burned by vegetation type for Fall for each of the prescribed fire scenarios are modeled.

Table 6 - Sensitivity For Prescribed Fires Sign-on Scenarios					
Veg Type	% of Total BA For Acres	Burn Type	Average Unit Size	Number of units	Acres
Grass	0		0	0	0
Shrub	2.4	Underburn	81	15	1,465
Ponderosa Pine	0.1	Underburn	27	1	23
	11.4	Fire	19	55	1,073
	0.5	Broadcast	17	4	70
Mixed Conifer	0.1	Underburn	35	2	10
	79.6	Pile	10	600	9,385
	5.3	Broadcast	11	40	1,226
Totals	100%		14	754	13,887

Table 4b – Baseline + 100% for Prescribed Fires Fall Scenario					
Veg Type	% of Total Rx Fire Acres	Burn Type	Average Unit Size	Number of units	Acres
Shrub	10	Underburn	100	28	2,777
	6	Underburn	200	8	1,666
	4	Underburn	500	2	1,111
Ponderosa Pine	20	Underburn	30	185	5,553
	12	Underburn	100	33	3,332
	8	Underburn	250	9	2,221
Mixed Conifer	25	Pile	25	278	6,942
	15	Broadcast	30	139	4,165
Totals	100%		41	682	27,766

Table 4c – Baseline + 200% for Prescribed Fires Fall Scenario					
Veg Type	% of Total Rx Fire Acres	Burn Type	Average Unit Size	Number of units	Acres
Shrub	10	Underburn	100	42	4,165
	6	Underburn	200	12	2,499
	4	Underburn	500	3	1,666
Ponderosa Pine	20	Underburn	30	278	8,330
	12	Underburn	100	50	4,998
	8	Underburn	250	13	3,332
Mixed Conifer	25	Pile	25	416	10,412
	15	Broadcast	30	208	6,247
Totals	100%		41	1,023	41,649

Table 4b - Quality for Forested Plots Full Sample

Veg Type	% of Total Ha Plot Acres	Burn Type	Average Dur. Yrs	Number of units	Acres
Shrub	10	Dormant	100	24	2,172
	6	Growing	100	3	1,505
	4	Low Season	67%	2	1,111
Ponderosa Pine	30	Dormant	5%	175	5,525
	12	Growing	10%	15	3,142
	9	Low Season	75%	9	2,357
Mixed Conifer	25	Fall	5%	175	4,342
	15	Fall Dormant	5%	120	1,455
Totals	100%		41	347	37,758

Table 4c - Forested 100% for Prescribed Fire Full Scenario

Veg Type	% of Total Ha Plot Acres	Burn Type	Average Dur. Yrs	Number of units	Acres
Shrub	10	Dormant	100	42	4,102
	6	Growing	67%	12	2,457
	4	Low Season	50%	3	1,638
Ponderosa Pine	30	Dormant	5%	175	8,750
	12	Growing	10%	50	5,000
	9	Low Season	50%	15	3,750
Mixed Conifer	25	Fall	5%	116	10,412
	15	Fall Dormant	5%	30	6,247
Totals	100%		41	1,027	41,049

Table 4d – Baseline + 300% for Prescribed Fires Fall Scenario					
Veg Type	% of Total Rx Fire Acres	Burn Type	Average Unit Size	Number of units	Acres
Shrub	10	Underburn	100	56	5,553
	6	Underburn	200	17	3,332
	4	Underburn	500	4	2,221
Ponderosa Pine	20	Underburn	30	370	11,106
	12	Underburn	100	67	6,664
	8	Underburn	250	18	4,443
Mixed Conifer	25	Pile	25	555	13,883
	15	Broadcast	30	278	8,330
Totals	100%		41	1364	55,532

Table 4e – Baseline + 500% for Prescribed Fires Spring Scenarios					
Veg Type	% of Total Rx Fire Acres	Burn Type	Average Unit Size	Number of units	Acres
Shrub	12.5	Underburn	200	52	10,412
	7.5	Underburn	500	12	6,247
	5	Underburn	1000	4	4,165
Ponderosa Pine	25	Underburn	35	595	20,825
	15	Underburn	150	83	12,495
	10	Underburn	500	17	8,330
Mixed Conifer	15	Pile	25	500	12,495
	10	Broadcast	30	278	8,330
Totals	100%		54	1541	83,298

Table 44 - Revenue + 200% for Preferred Tier LPO Accounts

Veg Type	% of Total Rx Fills Across	Base Type	Average Unit Size	Number of Units	Acres
Small	40	Big Shoot	100	50	2,500
	6	Gladiator	150	17	2,550
	4	Grandpa	300	4	1,212
Production Plus	20	Gladiator	30	250	11,100
	11	Gladiator	300	67	5,566
	8	Gladiator	250	18	1,944
Mixed Cocktail	25	Pile	25	555	10,000
	15	Broadcast	75	272	8,500
Totals	100%		41	1,934	52,272

Table 45 - Revenue + 200% for Preferred Tier LPO Accounts

Veg Type	% of Total Rx Fills Across	Base Type	Average Unit Size	Number of Units	Acres
Small	35	Gladiator	50	52	10,214
	15	Gladiator	150	12	6,[illegible]
	5	Grandpa	300	4	4,165
Production Plus	35	Gladiator	37	555	10,000
	15	Gladiator	150	45	15,[illegible]
	10	Gladiator	500	7	8,220
Mixed Cocktail	15	Pile	25	301	12,[illegible]
	10	Broadcast	50	218	9,[illegible]
Totals	100%		34	1,311	74,[illegible]

Table 4f – Baseline + 750% for Prescribed Fires Fall Scenario					
Veg Type	% of Total Rx Fire Acres	Burn Type	Average Unit Size	Number of units	Acres
Shrub	12.5	Underburn	250	74	14,751
	7.5	Underburn	500	18	8,850
	5	Underburn	1000	6	5,900
Ponderosa Pine	25	Underburn	35	843	29,501
	15	Underburn	150	118	17,701
	10	Underburn	500	24	11,801
Mixed Conifer	15	Pile	25	708	17,701
	10	Broadcast	30	393	11,801
Totals	100%		54	2183	118,006

Table 4g – Baseline + 1000% for Prescribed Fires Fall Scenario					
Veg Type	% of Total Rx Fire Acres	Burn Type	Average Unit Size	Number of units	Acres
Shrub	12.5	Underburn	200	95	19,089
	7.5	Underburn	500	23	11,453
	5	Underburn	1000	8	7,636
Ponderosa Pine	25	Underburn	35	1091	38,178
	15	Underburn	150	153	22,907
	10	Underburn	500	31	15,271
Mixed Conifer	15	Pile	25	916	22,907
	10	Broadcast	30	509	15,271
Totals	100%		54	2825	152,713

Table 4h – Baseline + 1500% for Prescribed Fires Fall Scenario					
Veg Type	% of Total Rx Fire Acres	Burn Type	Average Unit Size	Number of units	Acres
Shrub	12.5	Underburn	500	56	27,766
	7.5	Underburn	1000	17	16,660
	5	Underburn	2000	6	11,106
Ponderosa Pine	30	Underburn	70	952	66,638
	18	Underburn	300	133	39,983
	12	Underburn	1000	27	26,655
Mixed Conifer	10	Pile	25	889	22,213
	5	Broadcast	30	370	11,106
Totals	100%		91	2448	222,128

Figures 1, 2, and 3 show the change graphically between management scenarios for number of prescribed fire units, and acres burned, and average unit size for each management scenario modeled.

Figure 1. Acres Burned by Prescribed Fire
Spring and Fall Scenarios

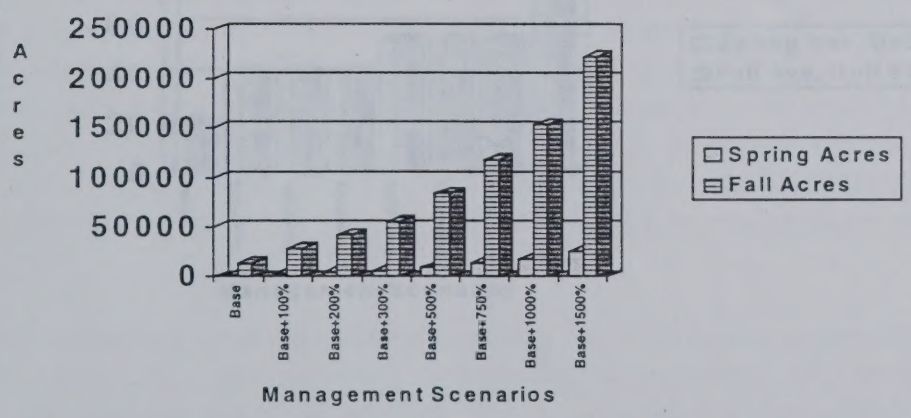


Table 3b - Baseline - 1500's for Three Dead Fires Fall Scenario

Veg Type	% of Total Fire Acres	Burn Type	Average Unit Size	Number of Units	Acres
Shrub	25	Crown burn	300	56	27,750
	25	Surface burn	100	17	16,667
	5	Underburn	20	6	11,100
Ponderosa Pine	30	Crown burn	70	852	60,225
	10	Surface burn	400	135	54,000
	10	Underburn	1000	27	27,025
Mixed Conifer	10	Pole	25	800	20,015
	5	Pole/Mature	30	370	11,105
Totals	100%		91	2435	222,135

Figures 1, 2, and 3 show the change graphically between average annual acreages for an hour of prescribed fire units, and acres burned, and a change in unit size for each management scenario ratio 1:1.

Figure 1. Acres Burned by Prescribed Fire
Spring and Fall Scenarios

Figure 2. Number of Prescribed Fires Burned Spring and Fall Scenarios

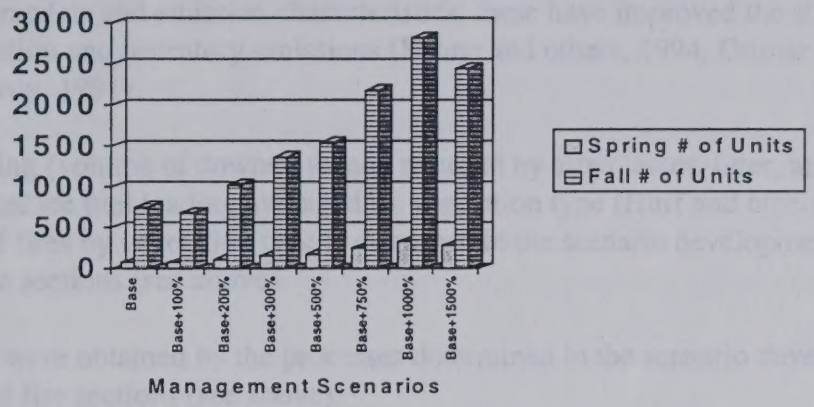
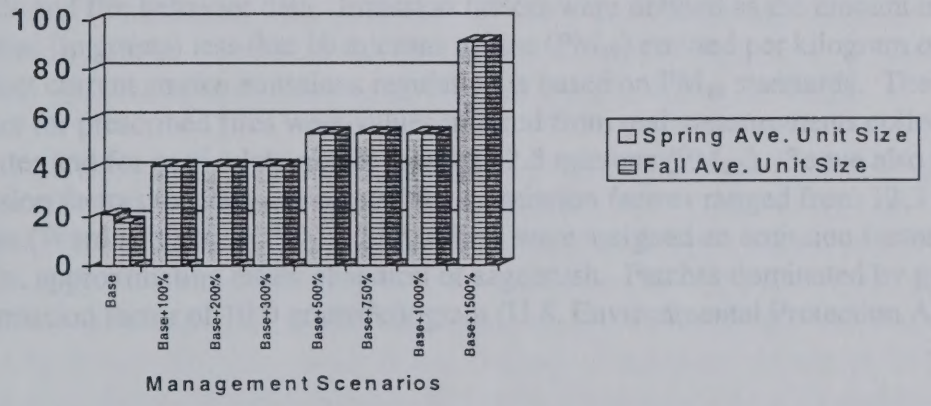


Figure 3. Average Unit Size of Prescribed Fires Burned Spring and Fall Scenarios



Smoke Production

The factors essential for determining smoke production are: (1) fuel loading, (2) area burned, (3) fuel consumption, and (4) emission factors (Peterson, 1988). These are the factors that were used in developing the smoke production for each day of the prescribed fire and wildfire scenario runs. Recent research in the Pacific Northwest and the Intermountain Regions has led to improved fuel consumption models and emission characteristics; these have improved the ability to estimate smoke production and inventory emissions (Keane and others, 1994, Ottmar and others, 1993, Ward and Hardy, 1991).

The fuel loading (volume of downed woody material by size classes, litter, and duff) used were averages of surface fuel loading averaged by vegetation type (Huff and others, 1995). The distribution of fires by vegetation type is discussed in the scenario development for wildfire and prescribed fire sections (see above).

Acres burned were obtained by the processes determined in the scenario development for wildfire and prescribed fire sections (see above).

Ottmar used the CONSUME model to estimate fuel consumption (Ottmar and others, 1993). Most of the model inputs were held constant except moisture for large fuels (7.6 to 22.9 centimeter-in-diameter woody material), time of ignition (for prescribed fires), and fuel loading among the different vegetation types. For all estimates of fuel consumption derived by the model, a constant wind speed of 4.8 kilometers/hour, slope of 20 percent, and 12 percent fuel moisture for 0.64 to 2.54 centimeter-in-diameter woody material.

The emission factors were assigned as a fire-average factor for prescribed fires corresponding to each set of fuels and fire behavior data. Emission factors were defined as the amount of particulate matter (in grams) less that 10 microns in size (PM_{10}) emitted per kilogram of fuel consumed. Most current smoke emissions regulation is based on PM_{10} standards. The PM_{10} emission factors for prescribed fires were values inferred from real measurements collected for all particulate matter and for particulate matter less than 2.5 microns ($PM_{2.5}$). So we also had available emission factors for $PM_{2.5}$. Forested fuels emission factors ranged from 12.5 to 10.2 grams/kilogram (Ward and Hardy 1991). Shrub fuels were assigned an emission factor of 10.6 grams/kilogram, approximating either chaparral of sagebrush. Patches dominated by grass were assigned the emission factor of 10.0 grams/kilogram (U.S. Environmental Protection Agency, 1991).

For wildfire emissions, a ratio derived by an average of 14.9 grams/kilogram, as calculated by Hardy and others (1992), divided by the prescribed fire emission factor for Douglas-fir/hemlock (the fuel type closest to that of the wildfire). This ratio was then multiplied by each emission factor to determine a wildfire emission factor, except for grass and shrub vegetation types.

To determine smoke emission production the amount of fuel consumed, derived by the CONSUME model, was multiplied by the total area burned to determine total smoke emission produced.

In addition heat release rates resulting from the prescribed fire and wildfire scenarios were derived using the Emissions Production Model (EPM). This data was needed to determine the height of plume development.

ANALYSIS

The analysis of the impact of the various management scenarios for prescribed fire and scenarios for wildfire was contracted to Earth Tech, Concord, MA. The contract was to provide a regional air quality modeling study to the Columbia River Basin. The dispersion modeling to assess the air quality impacts of prescribed and wildfire was done using CALPUFF non-steady-state dispersion model (Scire and others, 1995a).

For an in depth review of the analysis process refer to Appendix 1, (Scire and Tino, 1996).

RESULTS

The National Ambient Air Quality Standard (NAAQS) for PM_{10} is 150 $\mu g/m^3$ for a twenty-four average. There is no currently established standard for $PM_{2.5}$, but we have used an assumed threshold of 60 $\mu g/m^3$ for a twenty-four average. For all the scenarios that were modeled only the wildfire scenarios produced predicted concentrations above either of these threshold values. The predicted concentrations for the prescribed fire scenarios are substantially lower for several reasons: (1) the acreage burned with the prescribed fires are generally lower; (2) dispersion conditions during the spring and fall prescribed burn episodes are better, (3) there are larger numbers and a larger spatial distribution of prescribed fires. Although a compensating factor is the larger buoyancy and potentially higher plume rise of the wildfire plumes compared tot he smaller prescribed fire plumes. The wildfire plumes may start out higher, but they eventually mix to the ground and result in higher ground level concentrations of PM_{10} and $PM_{2.5}$.

For the regional modeling analysis, a modeling domain covering 1300 km x 1060 km and was gridded into 65 x 53 20-km cells. This domain includes all of the Columbia river basin and an appropriate buffer zone around the edges of the area of interest to allow for the effects of recirculating wind flows and boundary effects to be accounted (see Scire and Tino, 1996, p. 2-4). The number of grid cells with a 24-hour average concentration above the threshold values are shown in Table 5a through 5f. There were no exceedances of the threshold values for any of the prescribed burn simulations. Wildfire scenario #2 has the highest number of exceedances of the PM_{10} threshold value (190 for the 100% emissions case). Wildfire scenario #1 has the largest number of grid cells exceeding the $PM_{2.5}$ threshold (443 for the 100% emissions case). All of the nine wildfire scenarios had at least some exceedances of the threshold values for PM_{10} and $PM_{2.5}$.

In addition, heat release rates were calculated for the prescribed fires using fuelbed data and wildfire scenarios were derived using the Fuelmanager Production Model (FMM). This data was used to examine the feasibility of prescribed fire plume development.

ANALYSIS

The analysis of the impact of a wildfire management scenario relies on plots for prescribed fire and scenarios for wildfires were constructed in Excel 7.0a (Microsoft, 1995). The computer was used to provide a regional air quality analysis using a model for the Columbia River Basin. The simplified model is used to assess the air quality impacts of prescribed fire and wildfire management using CALPUFF, a non-steady-state dispersion model (Scire et al. 1990a).

For an in depth review of the analysis procedures refer to Appendix A, Scire and Thno, (1997).

RESULTS

The National Ambient Air Quality Standards (NAAQS) for PM$_{10}$ are 150 ug/m^3 for a two-day average. There is no currently existing standard for PM$_{2.5}$. For PM$_{10}$ we have used an assumed threshold of 60 ug/m^3 for a two-day average. For all data scenarios that were modelled with the wildfire scenarios pm$_{2.5}$ and pm$_{10}$ had the same values on account of their fuelbed values. The predicted plume structures for the prescribed fire scenarios are not identical, however, for several reasons: (1) the acreage treated with the prescribed fire is not proportionally to scale; (2) depending on conditions during the spring and fall prescribed burn cycles, the latter, (3) there are larger numbers and a larger spatial distribution of prescribed fires in the Fall. Although a comparable fuelbed is the larger burn acreage and potentially higher plume tops of the wildfire plumes compared to the smaller prescribed burn plumes. The wildfire plumes may also be higher, but they are more likely to the ground and reach in higher ambient level concentrations of PM$_{10}$ and PM$_{2.5}$.

For the regional modelling analysis, modelling domain covering 1500 km x 1500 km and was gridded into 65 x 55 20-km cells. This domain includes all of the Columbia River Basin and an appropriate buffer zone surrounding the edges of the area of interest to allow for the effects of recirculating wind flows and boundary effects to be accounted (Scire and Thno, 1994, p. 24). The numbers of grid cells with a 24-hour average concentration across the threshold values, as shown in Figure 5a through 5f. There were no exceedances of the threshold values for any of the prescribed burn simulations. Wildfire scenario #2 has the highest number of exceedances of the PM$_{10}$ threshold value (150 for the 100% emissions case). Wildfire scenario #1 has the largest number of grid cells exceeding the PM$_{10}$ threshold (445 for the 100% emissions case). All of the wildfire scenarios had at least some exceedances of the threshold values for PM$_{10}$ and PM$_{2.5}$.

Table 5a - Summer Wildfire Scenario #1			
Number of Grid Cells with PM_{10} Concentrations above 150 $\mu g/m^3$			
	Scenario		
Day	100%	50%	25%
8/6/90	0	0	0
8/7/90	0	0	0
8/8/90	2	0	0
8/9/90	5	1	1
8/10/90	25	6	3
8/11/90	49	36	15
8/12/90	28	4	0
8/13/90	1	0	0
Total	110	47	19

Table 5b - Summer Wildfire Scenario #1			
Number of Grid Cells with $PM_{2.5}$ Concentrations above 60 $\mu g/m^3$			
	Scenario		
Day	100%	50%	25%
8/6/90	0	0	0
8/7/90	0	0	0
8/8/90	5	2	1
8/9/90	41	4	2
8/10/90	65	24	9
8/11/90	130	75	42
8/12/90	157	100	29
8/13/90	45	2	0
Total	443	207	83

Table 5c - Summer Wildfire Scenario #2			
Number of Grid Cells with PM_{10} Concentrations above 150 $\mu g/m^3$			
	Scenario		
Day	100%	50%	25%
8/6/90	1	0	0
8/7/90	1	0	0
8/8/90	12	4	0
8/9/90	55	20	1
8/10/90	56	16	3
8/11/90	29	0	0
8/12/90	26	5	0
8/13/90	10	0	0
Total	190	45	4

Table 5d - Summer Wildfire Scenario #2			
Number of Grid Cells with $PM_{2.5}$ Concentrations above 60 $\mu g/m^3$			
	Scenario		
Day	100%	50%	25%
8/6/90	1	0	0
8/7/90	1	0	0
8/8/90	12	4	0
8/9/90	49	17	1
8/10/90	40	16	2
8/11/90	24	0	0
8/12/90	24	4	0
8/13/90	9	0	0
Total	160	41	3

Table 5e - Summer Wildfire Scenario #3			
Number of Grid Cells with PM_{10} Concentrations above 150 $\mu g/m^3$			
	Scenario		
Day	100%	50%	25%
8/6/90	2	1	1
8/7/90	8	2	0
8/8/90	6	1	0
8/9/90	5	1	0
8/10/90	25	5	1
8/11/90	14	1	0
8/12/90	14	0	0
8/13/90	7	2	1
Total	81	13	3

Table 5f - Summer Wildfire Scenario #3			
Number of Grid Cells with $PM_{2.5}$ Concentrations above 60 $\mu g/m^3$			
	Scenario		
Day	100%	50%	25%
8/6/90	2	1	1
8/7/90	8	2	0
8/8/90	6	1	0
8/9/90	5	1	0
8/10/90	25	5	1
8/11/90	14	1	0
8/12/90	14	0	0
8/13/90	7	2	1
Total	81	13	3

To determine of effect of smoke production of the various scenarios upon visibility a haziness index expressed in deciview (Pitchford and Malm, 1994). A change in one deciview corresponds to an approximate 10% change in extinction coefficient, which is considered a small, but perceptible change in visibility. When considering the impacts of smoke production upon visibility a person should understand that if the visibility of a area is quite high a relatively small amount of smoke can be perceptible, while if the area has relatively poor visibility a greater amount of smoke would need to be produced to create a perceptible change.

The number of grid cells where the change in haziness (or visibility) exceeded one deciview was computed for each simulation. Tables 6a through 6c contain the analysis of the for the prescribed burn scenarios on the regional domain. The regional grid, as noted previously, contains 3,445 grid cells (65x53) with a grid spacing of 20 km. Up to 4.5%, 7.2%, and 32% of the domain was predicted to have a perceptible change in visibility with the highest emission scenario on at least one of the days, in early spring, late spring, and fall episodes, respectively. The results of the wildfire simulations are tabulated in Table 6e. Up to 75% of the grid cells have a perceptible change in visibility during the highest emission scenario.

Table 6a - Early Spring Episode					
Number of Grid Cells with Δ dv $\geq$ 1 - Regional Domain					
Emission Scenario					
	3/27	**3/28**	**3/29**	**3/30**	**3/31**
Base	21	17	17	5	12
Base + 100%	21	33	27	16	20
Base + 200%	28	38	59	46	28
Base + 300%	46	42	64	37	44
Base + 500%	46	65	72	42	51
Base + 750%	84	84	112	79	81
Base + 1000%	149	92	147	133	125
Base + 1500%	154	132	183	197	127

Table 6b - Late Spring Episode							
Number of Grid Cells with Δ dv ≥ 1 -Regional Domain							
Emission Scenario							
	5/4	5/5	5/6	5/7	5/8	5/9	5/10
Base	11	13	9	12	16	14	13
Base + 100%	20	52	22	39	40	23	0
Base + 200%	44	61	33	35	50	15	0
Base + 300%	56	52	38	68	58	15	9
Base + 500%	71	114	72	87	129	26	0
Base + 750%	108	112	80	100	107	64	7
Base + 1000%	119	138	106	145	218	88	10
Base + 1500%	142	249	158	128	210	131	136

Table 6c - Fall Episode						
Number of Grid Cells with Δ dv ≥ 1 -Regional Domain						
Emission Scenario						
	10/14	10/15	10/16	10/17	10/18	10/19
Base	109	40	76	80	64	147
Base + 100%	162	111	158	149	121	231
Base + 200%	295	166	248	224	241	355
Base + 300%	399	320	332	334	312	476
Base + 500%	510	477	612	502	423	623
Base + 750%	707	700	886	751	609	844
Base + 1000%	782	805	1176	941	729	1038
Base + 1500%	792	836	1307	1239	680	1099

Table 6b - Late Spring Episode								
Number of Grid Cells with Δ dv ≥ 1 - Regional Domain								
Emission Scenario								
	824	853	895	927	958	997	1030	
Base	11	13	9	12	16	14	15	
Base + 10%	30	52	32	39	41	23	0	
Base + 20%	44	61	37	35	50	15	0	
Base + 30%	50	53	58	58	57	15	3	
Base + 50%	71	114	72	97	120	20	0	
Base + 75%	108	112	80	100	107	64	0	
Base + 100%	119	138	100	145	218	53	10	
Base + 150%	147	248	133	128	210	101	15	

Table 6c - Fall Episode								
Number of Grid Cells with Δ dv ≥ 1 - Regional Domain								
Emission Scenario								
	1014	1035	1046	1077	1098	1019		
Base	109	46	76	80	94	147		
Base + 10%	165	174	138	149	121	251		
Base + 20%	295	156	246	224	241	255		
Base + 30%	399	320	332	334	312	276		
Base + 50%	510	477	617	702	423	525		
Base + 75%	707	700	886	751	609	344		
Base + 100%	722	805	1176	941	750	1018		
Base + 150%	792	976	1307	1239	980	1039		

Table 6d - Summer Episodes									
Number of Grid Cells with Δ dv ≥ 1 -Regional Domain									
Episode	Emission Scenario								
		8/6	8/7	8/8	8/9	8/10	8/11	8/12	8/13
#1	25%	9	103	107	281	432	685	910	1061
#1	50%	19	215	242	470	737	1080	1314	1597
#1	100%	26	322	402	757	1077	1541	1900	2238
#2	25%	88	551	636	792	768	1043	1194	1443
#2	50%	104	735	1040	1434	1363	1543	1820	2089
#2	100%	130	914	1327	1859	1807	2092	2305	2570
#3	25%	82	471	767	878	808	979	1186	1468
#3	50%	109	599	976	1177	1075	1294	1723	2155
#3	100%	159	720	1121	1408	1350	1735	2383	2437

Similar analysis was also completed for a fine scale analysis area (2500 grid cells in a 50 x 50 grid with a spacing of 4 km). This area took in the northern end of the Blue Mountains in northeast Oregon and extended into southwest Idaho and into southeast Washington. This area showed similar patterns of effect as did the Regional Domain analysis, but at a lesser scale of impacts. The fine scale analysis did not give a good representation of wildfire effects for either particulate matter impacts or visibility impacts as the modeling process used did not include impacts from outside this smaller area and little fire activity occurred in this area in the days used for the wildfire analysis. The fine scale analysis at this point seems of very little value.

CONCLUSIONS

Fire is a part of the natural processes of the Columbia River Basin and vital in maintaining ecosystem functions in this region. The use of prescribed fire as a tool to return fire to the ecosystem is very likely to increase in most of the alternatives considered in the Environmental Impact Studies for the Columbia River Basin. This modeling effort would indicate that prescribed fire could be used at intense levels of activity (such as 220,000 + acres in a six day period) with little chance of producing impacts to National Ambient Air Quality Standards for particulate matter (PM_{10}). The modeling would also indicate that perceptible changes in visibility (or haziness) can result over a large portion of the basin from the most intense use of prescribed fire.

Huff and others (1995), concluded (and we feel it pertinent to this study also) that:

> One of the most important tradeoffs to consider is the substantial increase in smoke production from wildfires versus prescribed fire. Wildfires occur when fuels are dry, fuel consumption is greater, and the fuels are consumed during the less efficient smoldering stage, which nets about twice as much PM_{10} when compared to prescribed fire. If prescribed fire can be used to restore or maintain fire-adapted ecosystems, yet reduce the potential of wildfire, PM10 production from landscape burning could be reduced considerably. In addition, prescribed fires are planned in advance, and four mitigation techniques are available to further reduce air quality impacts. Managed ignitions can be planned for situations when (1) smoke will disperse quickly, (2) smoke will avoid sensitive airsheds, (3) less fuel will be consumed more efficiently and produce less smoke, and (4) fuels have been removed or reduced, thereby eliminating the need to burn. In cases where specific objectives are to be met, some of these mitigation techniques may not be employed to the fullest extent possible.
>
> Wildfires are not planned; therefore, there is little opportunity to employ mitigation techniques except to suppress the fire as quickly as possible. The smoke generated will be directed and concentrated according to the prevailing wind and atmospheric stability. This will often occur during the summer months when fuel moisture is low, fuel consumption and smoke production are high, and stable atmospheric conditions may persist. Wildfire does not have one advantage over prescribed fire: it might not occur. Will the public be willing to accept smoke from prescribed fires spread over a period of years or find it preferable to gamble that a catastrophic wildfire, which sends out large amounts and greater concentrations of smoke in a few months, will not occur?
>
> It is commonly noted that if we do not prescribe burn now, wildfire may soon do the job in a much less acceptable way, from both ecosystem and air quality standpoints. This premise will not be accepted by society and cannot be used as an excuse for not providing quality information about potential impacts of prescribed burning for forest health. .....

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Appendix A

Modeling of Wildfire and Prescribed Burn Scenarios in the Columbia River Basin

Volume I

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Modeling of Wildfire and Prescribed Burn Scenarios in the Columbia River Basin

Volume I

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Modeling of Wildfire and Prescribed Burn Scenarios in the Columbia River Basin

Volume I

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TABLE OF CONTENTS

1. Introduction 1-1

2. Meteorological Modeling 2-1

   2.1 Overview of CALMET 2-1
   2.2 Domain and Grid 2-3
   2.3 Meteorological Stations 2-6

3. Dispersion Modeling 3-1

   3.1 Overview of CALPUFF 3-1
   3.2 Model Options 3-5

4. Summary of Modeling Results 4-1

5. References 5-1

Appendix A[1]: Daily Weather Maps

Appendix B[1]: MM4-FDDA Vector Plots for 80-km Grid

Appendix C[1]: CALMET Vector Plots for 20-km Grid

Appendix D[1]: Emission Tables - Base Case Scenarios

Appendix E[2]: Contour Plots of CALPUFF Concentrations of PM_{10} and $PM_{2.5}$ due to fires

Appendix F[3]: CALMET Vector Plots for 4-km Grid (Microscale Domain)

Appendix G[3]: Contour Plots of CALPUFF Concentrations of PM_{10} and $PM_{2.5}$ due to fires (Microscale Domain)

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[1] In Volume II

[2] In Volume III

[3] In Volume IV

1. INTRODUCTION

The U.S. Forest Service (USFS) and the Bureau of Land Management (BLM) have responsibility to develop environmental impact statements for management of lands under their jurisdiction in the Columbia River Basin. Selection of land management strategies will affect the amounts and impacts of prescribed burns and wildfires in the Pacific Northwest. To provide support for the land management strategy selection process, dispersion modeling has been used to assess the air quality impacts of prescribed and natural burning. In this study, the results of a regional air quality modeling study of the Columbia River Basin are presented that is based on the CALPUFF non-steady-state dispersion model (Scire et al., 1995a). Provided are estimates of air quality impacts due to particulate matter emitted from various burning scenarios that may result from the land management alternatives under consideration for the Columbia River Basin.

The USFS has developed estimates of time-dependent emission rates of particulate matter less than 10 microns diameter (PM_{10}) and less than 2.5 microns diameter ($PM_{2.5}$) as well as heat release rates resulting from various prescribed burn and wildfire scenarios using the Emissions Production Model (EPM). A set of four meteorological episodes during 1990 of length 5-8 days were evaluated. They include:

- An early spring episode representing typical prescribed burning conditions in the southern part of the Columbia River Basin below the 46th parallel.
- A late spring episode representing typical prescribed burning conditions in the northern part of the Columbia River Basin above the 46th parallel.
- A summer episode during which a high frequency of wildfires occurred.
- A fall episode representing the fall burning season for both the northern and southern parts of the Columbia River basin.

For the spring and fall prescribed burn meteorological episodes, eight different emission scenarios were evaluated, based on different assumptions of acreage burned, burn locations, and burn types (e.g., underburns, broadcast burns, pile burns). The prescribed burn scenarios included a base case acreage scenario, and the base case plus 100%, 200%, 300%, 500%, 750%, 1000% and 1500% of the base case acreage. For example, the acreage burned in the base + 100% case was approximately double that of the base case. For the summer wildfire episode, three wildfire scenarios were developed by the USFS based on an analysis of actual wildfires during 1990 and 1994. The

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emissions developed from the actual wildfires were applied to the 1990 summer meteorological episode. In addition, for each of the three wildfire scenarios, emissions were evaluated at three levels of acreage burned (100%, 50%, and 25% of actual), resulting in a total of nine wildfire emission scenarios being evaluated for the summer episode.

The dispersion modeling was performed on two domains. A regional domain included all of Washington, Oregon, Idaho, and parts of northern California, Nevada, and Utah, and western Montana and Wyoming. The domain was divided into a grid of 65 x 53 square cells with sides of length 20 km. A second domain with finer grid resolution covered northeastern Oregon, southeastern Washington, and west-central Idaho. The fine-scale domain involved a grid of 50 x 50 grid cells with a resolution of 4 km.

Gridded fields of winds and other meteorological variables were developed for both domains using the CALMET diagnostic meteorological model (Scire et al., 1995b). Coarse-grid (80-km) wind data from the Mesoscale Model Version 4 with Four Dimensional Data Assimilation (MM4-FDDA) (Anthes et al., 1987; Stauffer et al., 1990) and observational data from National Weather Service (NWS) surface and upper air stations in the domain were input into the CALMET model. Chapter 2 contains a description of the meteorological modeling performed.

The CALPUFF model is a non-steady-state puff model designed to produce estimates of ambient concentrations and visibility impacts from multiple, time-varying point, area, and line sources. In this analysis, the fires were treated as buoyant area sources. Plume rise was estimated using a numerical, non-Boussinesq plume rise module in CALPUFF that accounts for the initial plume size, buoyancy and momentum effects, vertical wind shear effects, plume radiative losses, and arbitrary temperature stratifications. A description of the CALPUFF modeling is provided in Chapter 3.

A summary of the modeling results is provided in Chapter 4. A set of appendices contain detailed meteorological and ambient concentration results for each of the four meteorological episodes and 8-9 emission scenarios (i.e., a total of 33 simulations of length 5-8 days). Appendix A shows the daily weather maps for each of the episode days. Appendix B contains plots of gridded wind MM4-FDDA 80-km wind vectors at two levels (10 meters and 3500 meters above the ground) one hour per day. The CALMET-generated 20-km gridded wind fields are shown in Appendix C. Appendix D contains tables listing the emissions for each of the base case emission scenarios. Appendix E contains 24-hour average values of predicted PM_{10} and $PM_{2.5}$ concentrations due to the fires on the 20-km regional grid resulting from each emission scenario. The gridded wind fields for the fine-scale grid are shown in Appendix F. The predicted PM_{10} and $PM_{2.5}$ concentrations on the fine-scale grid are presented in Appendix G.

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Gridded fields of winds and other meteorological variables were developed for each domain using the CALMET diagnostic meteorological model (Scire et al., 1995b). Coarse-grid (80-km) wind data from the Mesoscale Model Version 4 with Four Dimensional Data Assimilation (MM4-FDDA) (Anthes et al., 1987, Stauffer et al., 1990) and observational data from National Weather Service (NWS) surface and upper air stations in the domain were input into the CALMET model. Chapter 2 contains a description of the meteorological modeling performed.

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2. METEOROLOGICAL MODELING

2.1 Overview of CALMET

The CALMET meteorological model was used to produce the gridded fields of winds and other meteorological variables required by CALPUFF. CALMET consists of a diagnostic wind field module and micrometeorological modules for overwater and overland boundary layers. The model allows coordinates to be projected in a Lambert Conformal system to account for the curvature of the Earth's surface. The diagnostic wind field module uses a two-step approach to the computation of the wind fields (Douglas and Kessler, 1988), as illustrated in Figure 2-1. In the first step, an initial guess wind field is adjusted for kinematic effects of terrain, slope flows, and terrain blocking effects. The results of this analysis is the Step 1 field. The second step consists of an objective analysis procedure to introduce observational data into the Step 1 wind field to produce a final wind field. Gridded MM4-FDDA winds can be introduced into CALMET in three different ways:

- as the initial guess field (Pathway A in Figure 2-1);
- as the Step 1 field (Pathway B); or
- as "observations" in the objective analysis procedure (Pathway C).

If the MM4-FDDA wind data are used as the initial guess field (Pathway A), the coarse grid scale MM4-FDDA data are interpolated to the fine-scale CALMET grid. The diagnostic module in CALMET then adjusts the initial guess field for kinematic effects of terrain, slope flows, and terrain blocking effects using fine-scale CALMET terrain data to produce a Step 1 wind field. In this study, the MM4-FDDA winds were used as the Step 1 wind field (Pathway B). This field is then adjusted using observational data, but additional terrain adjustments are not made. That is, the response of the wind field to terrain is derived from the terrain influences imbedded in the MM4-FDDA wind fields. The Interagency Workgroup on Air Quality Modeling (EPA, 1995) evaluated the various CALMET options for interpolating 80-km MM4-FDDA data down to CALMET grid sizes of 54-km and 18-km. The use of 80-km MM4-FDDA winds as CALMET Step 1 winds provided the best correlation to nested grid MM4-FDDA reference fields at both 18-km and 54-km grid resolution. Therefore, in this study, the MM4-FDDA winds were used as the Step 1 field in CALMET.

The boundary layer modules in CALMET produce gridded fields of the surface friction velocity (u_*), Monin-Obukhov length (L), mixing height (z_i), convective velocity scale (w_*), PGT

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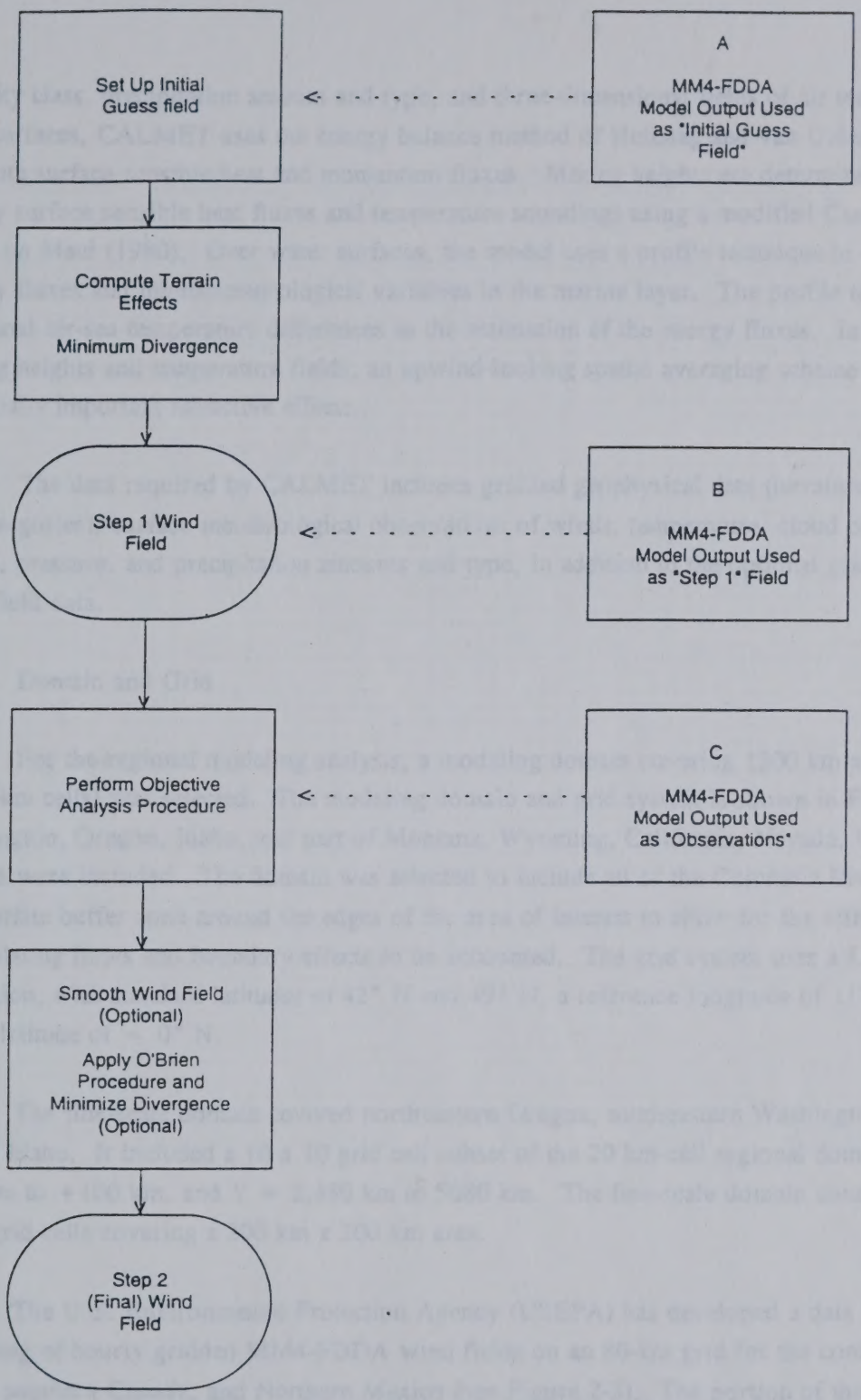

Figure 2-1. Flow diagram of the diagnostic wind model in CALMET. Winds derived from the MM4-FDDA model can be introduced as the initial guess field (A), the Step 1 field (B), or as "observations" (C).

stability class, precipitation amount and type, and three-dimensional fields of air temperature. Over land surfaces, CALMET uses the energy balance method of Holtslag and van Ulden (1983) to compute surface sensible heat and momentum fluxes. Mixing heights are determined from computed hourly surface sensible heat fluxes and temperature soundings using a modified Carson (1973) method based on Maul (1980). Over water surfaces, the model uses a profile technique to compute the energy fluxes and micrometeorological variables in the marine layer. The profile technique uses measured air-sea temperature differences in the estimation of the energy fluxes. In the case of the mixing heights and temperature fields, an upwind-looking spatial averaging scheme accounts for potentially important advective effects.

The data required by CALMET includes gridded geophysical data (terrain elevations and land use categories), surface meteorological observations of winds, temperature, cloud cover, ceiling height, pressure, and precipitation amounts and type, in addition to the optional gridded MM4-FDDA wind field data.

2.2 Domain and Grid

For the regional modeling analysis, a modeling domain covering 1300 km x 1060 km (65 x 53 20-km cells) was selected. The modeling domain and grid system is shown in Figure 2-2. All of Washington, Oregon, Idaho, and part of Montana, Wyoming, California, Nevada, Utah, and southern Canada were included. The domain was selected to include all of the Columbia River Basin and an appropriate buffer zone around the edges of the area of interest to allow for the effects of recirculating flows and boundary effects to be accounted. The grid system uses a Lambert Conformal projection, with standard latitudes of 42° N and 49° N, a reference longitude of 117° W, and an origin latitude of ~ 0° N.

The fine-scale domain covered northeastern Oregon, southeastern Washington, and west-central Idaho. It included a 10 x 10 grid cell subset of the 20 km-cell regional domain from X = -100 km to +100 km, and Y = 5,480 km to 5680 km. The fine-scale domain consisted of 50 x 50 4-km grid cells covering a 200 km x 200 km area.

The U.S. Environmental Protection Agency (USEPA) has developed a data base for 1990 consisting of hourly gridded MM4-FDDA wind fields on an 80-km grid for the continental United States, southern Canada, and Northern Mexico (see Figure 2-3). The portion of the MM4-FDDA domain extracted for use in the CALMET modeling was that covered by MM4-FDDA grid cells (46-71, 9-37). This is a slightly larger area than the regional CALMET domain shown in Figure 2-2.

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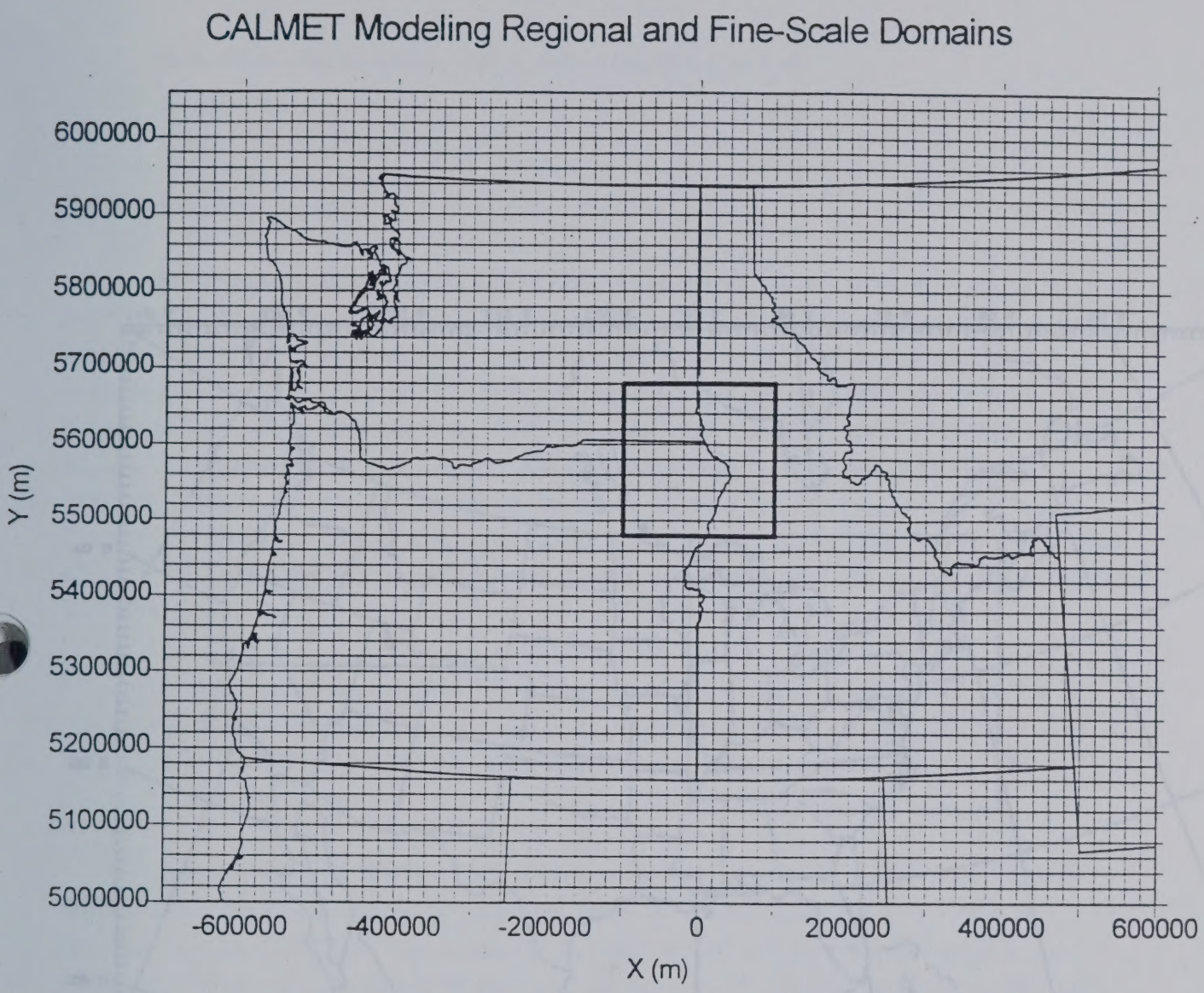

Figure 2-2. The regional Columbia River Basin CALMET modeling domain (outer box) and the fine-scale domain (inner box). The regional grid cell size is 20 km. The regional grid of 65 x 53 cells covers 1300 km x 1060 km. The fine-scale grid size is 4 km and covers a 200 km x 200 km area (50 x 50 cells).

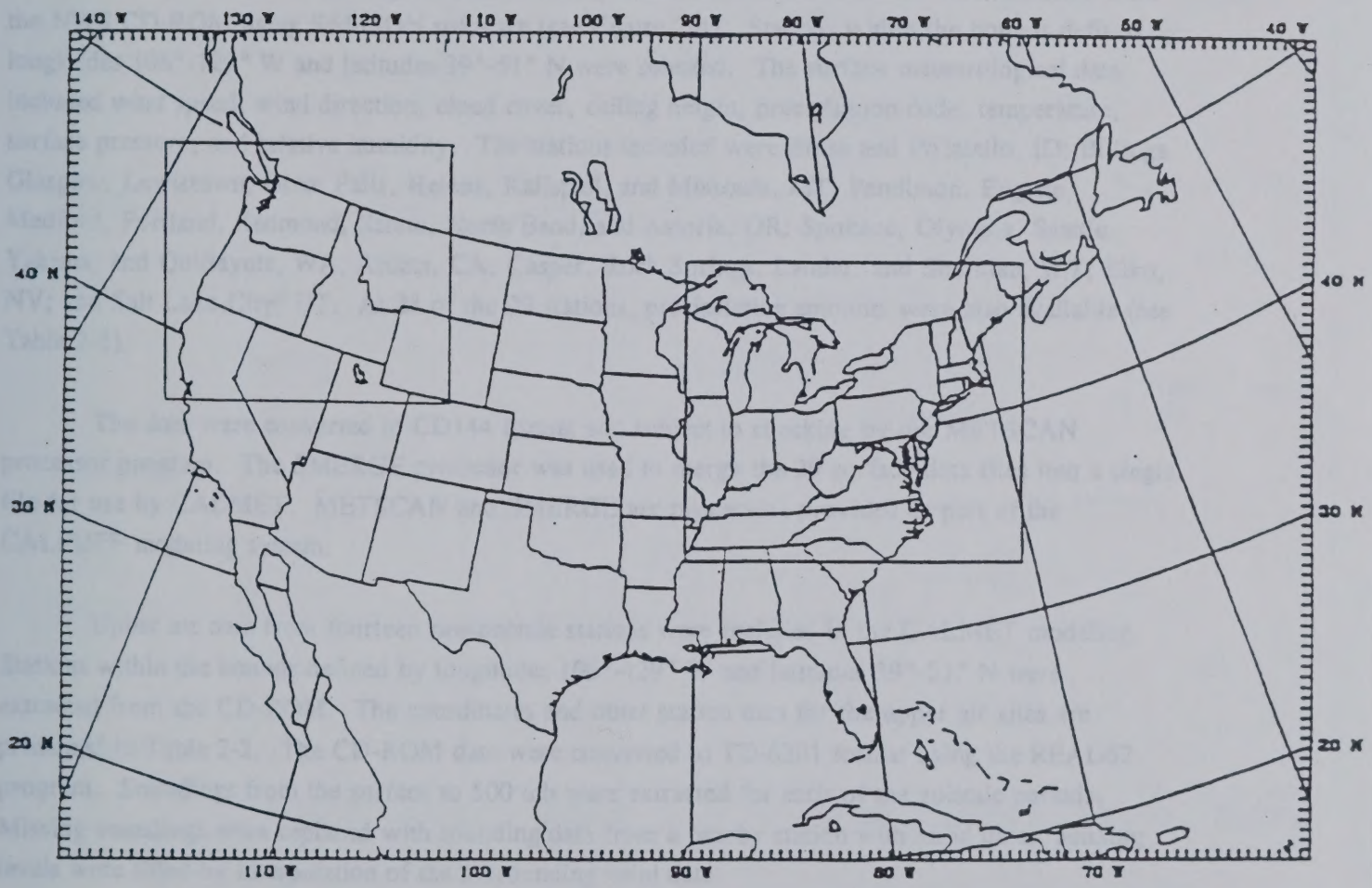

Figure 2-3. The MM4-FDDA master domain (outer box). The subdomain extracted for use in the regional CALMET modeling is shown in the inner box covering the Pacific Northwest. The MM4-FDDA grid size is 80 km.

CALMET was run with 11 vertical layers. The mid-point heights of the CALMET layers were:

10 m, 50 m, 100 m, 200 m, 400 m, 800 m, 1240 m, 1600 m,
2000 m, 2600 m, 3500 m

2.3 Meteorological Stations

Hourly surface meteorological data at twenty-nine observational stations were extracted from the NWS CD-ROM using SAMSON software (see Figure 2-4). Stations within the bounds defined by longitudes 106°-129° W and latitudes 39°-51° N were selected. The surface meteorological data included wind speed, wind direction, cloud cover, ceiling height, precipitation code, temperature, surface pressure, and relative humidity. The stations included were Boise and Pocatello, ID; Billings, Glasgow, Lewistown, Great Falls, Helena, Kalispell, and Missoula, MT; Pendleton, Eugene, Medford, Portland, Redmond, Salem, North Bend, and Astoria, OR; Spokane, Olympia, Seattle, Yakima, and Quillayute, WA, Arcata, CA; Casper, Rock Springs, Lander, and Sheridan, WY; Elko, NV; and Salt Lake City, UT. At 25 of the 29 stations, precipitation amounts were also available (see Table 2-1).

The data were converted to CD144 format and subject to checking by the METSCAN processor program. The SMERGE processor was used to merge the 29 surface data files into a single file for use by CALMET. METSCAN and SMERGE are processors provided as part of the CALPUFF modeling system.

Upper air data from fourteen rawinsonde stations were included in the CALMET modeling. Stations within the bounds defined by longitudes 106°-129° W and latitudes 39°-51° N were extracted from the CD-ROM. The coordinates and other station data for the upper air sites are presented in Table 2-2. The CD-ROM data were converted to TD-6201 format using the READ62 program. Soundings from the surface to 500 mb were extracted for each of the episode periods. Missing soundings were replaced with sounding data from a nearby station with valid data. Missing levels were filled by interpolation of the surrounding valid data.

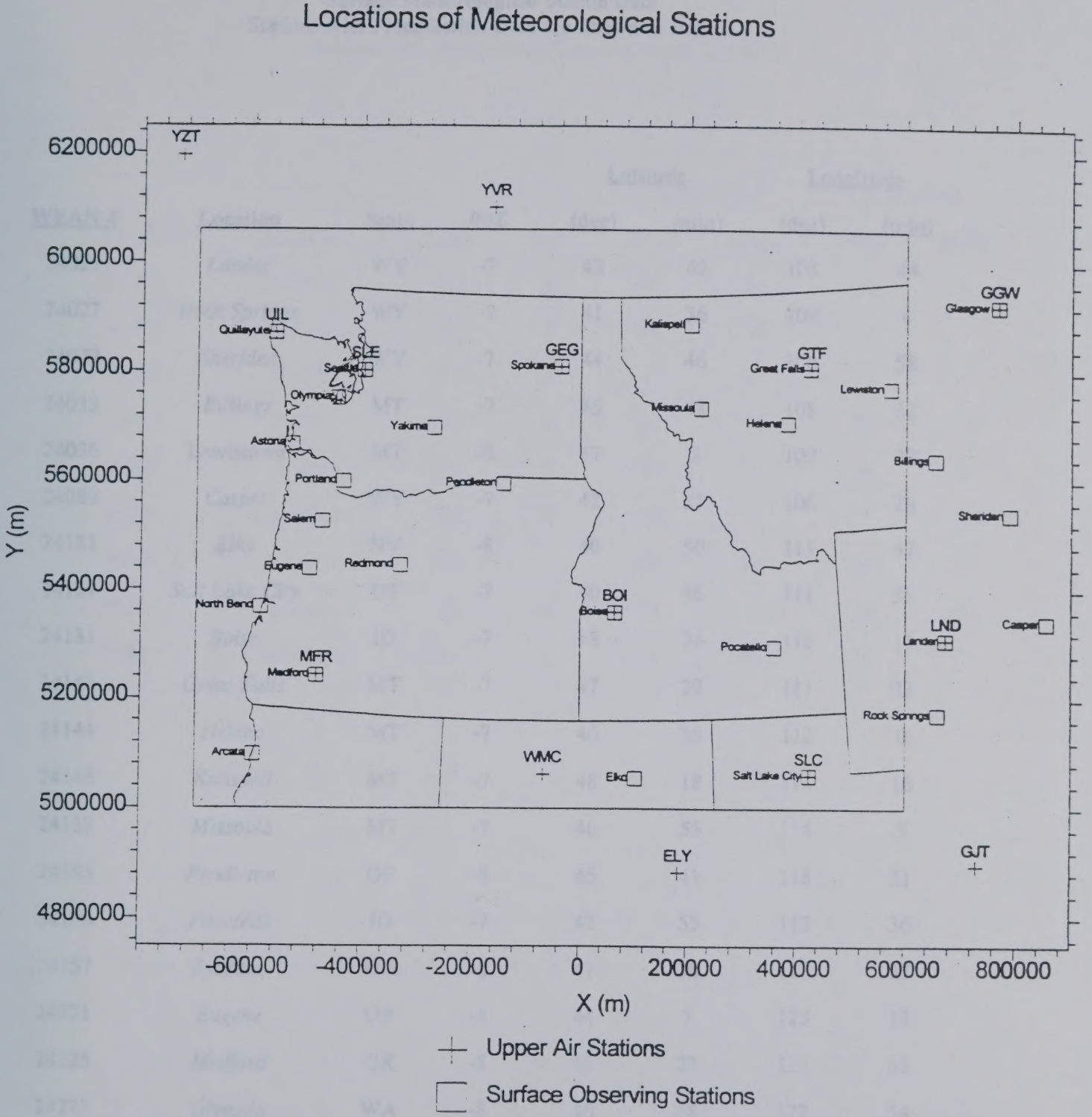

Figure 2-4. Locations of the surface and upper air stations used in the CALMET modeling.

Table 2-1
Surface Meteorological Station Data
Stations with Precipitation Data are Shown in *Italics*.

WBAN #	Location	State	00Z	Latitude (deg)	Latitude (min)	Longitude (deg)	Longitude (min)
24021	*Lander*	WY	-7	42	49	108	44
24027	*Rock Springs*	WY	-7	41	36	109	4
24029	*Sheriden*	WY	-7	44	46	106	58
24033	*Billings*	MT	-7	45	48	108	32
24036	Lewistown	MT	-8	47	3	109	27
24089	*Casper*	WY	-7	42	55	106	28
24121	*Elko*	NV	-8	40	50	115	47
24127	*Salt Lake City*	UT	-7	40	46	111	58
24131	*Boise*	ID	-7	43	34	116	13
24143	*Great Falls*	MT	-7	47	29	111	22
24144	*Helena*	MT	-7	46	36	112	0
24146	*Kalispell*	MT	-7	48	18	114	16
24153	*Missoula*	MT	-7	46	55	114	5
24155	*Pendleton*	OR	-8	45	41	118	51
24156	*Pocatello*	ID	-7	42	55	112	36
24157	*Spokane*	WA	-8	47	38	117	32
24221	*Eugene*	OR	-8	44	7	123	13
24225	*Medford*	OR	-8	42	22	122	52
24227	*Olympia*	WA	-8	46	58	122	54
24229	*Portland*	OR	-8	45	36	122	36

Table 2-1
Surface Meteorological Station Data
Stations with Precipitation Data are Shown in Italics.

Table 2-1 (Continued)
Surface Meteorological Station Data
Stations with Precipitation Data are Shown in *Italics*.

				Latitude		Longitude	
WBAN #	**Location**	**State**	**00Z**	**(deg)**	**(min)**	**(deg)**	**(min)**
24230	Redmond	OR	-8	44	16	121	9
24232	*Salem*	OR	-8	44	55	123	1
24233	*Seattle*	WA	-8	47	27	122	18
24243	*Yakima*	WA	-8	46	34	120	32
24283	Arcata	CA	-8	40	59	124	6
24284	North Bend	OR	-8	43	25	124	15
94008	*Glasgow*	MT	-7	48	13	106	37
94224	*Astoria*	OR	-8	46	9	123	53
94240	*Quillayute*	WA	-8	47	57	124	33

Table 2-2
Upper Air Station Data

WMO ID	WBAN #	Location	State	Latitude	Longitude
BOI	24131	Boise	ID	43.57	116.22
GEG	24157	Spokane	WA	47.63	117.53
GTF	24143	Great Falls	MT	47.48	111.35
MFR	24225	Medford	OR	42.38	122.87
SEA	24233	Seattle	WA	47.45	122.3
UIL	94240	Quillayute	WA	47.95	124.55
GGW	24034	Glasgow	MT	48.22	106.62
YZT	25223	Port Hardy	Brit. Colum.	50.68	127.37
YVR	25152	Vernon	Brit. Colum.	50.23	119.28
WMC	24128	Winnemucca	NV	40.9	117.8
SLC	24127	Salt Lake City	UT	40.77	111.97
LND	24021	Lander	WY	42.82	108.73
ELY	23154	Ely	NV	39.28	114.87
GJT	23032	Grand Junction	CO	39.07	108.57

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3. DISPERSION MODELING

3.1 Overview of CALPUFF

CALPUFF is a multi-species non-steady-state puff dispersion model designed to simulate the effects of time- and space-varying meteorological conditions on pollutant transport, dispersion, chemical transformation, and deposition. CALPUFF uses the three-dimensional winds and other meteorological fields generated by CALMET to drive the transport and dispersion process. One of its features important for the current study is its ability to simulate forest fires as buoyant area sources, and its interface to the Emissions Production Model (EPM). EPM is a U.S. Forest Service model that estimates time-varying emission rates and heat release rates for forest fires under various conditions and fire types (e.g., underburns, broadcast burns, pile burns).

The major features and options of the CALPUFF model are summarized in Table 3-1. The major technical algorithms are briefly described below.

Dry Deposition: A full resistance model is provided in CALPUFF for the computation of dry deposition rates of gases and particulate matter as a function of geophysical parameters, meteorological conditions, and pollutant species. Options are provided to allow user-specified, diurnally varying deposition velocities to be used for one or more pollutants instead of the resistance model (e.g., for sensitivity testing) or to by-pass the dry deposition model completely.

Wet Deposition: An empirical scavenging coefficient approach is used in CALPUFF to compute the depletion and wet deposition fluxes due to precipitation scavenging. The scavenging coefficients are specified as a function of the pollutant and precipitation type (i.e., frozen vs. liquid precipitation).

Chemical Transformation: CALPUFF includes options for parameterizing chemical transformation effects using the five species scheme (SO_2, SO_4^-, NO_x, HNO_3, and NO_3^-) employed in the MESOPUFF II model or a set of user-specified, diurnally-varying transformation rates. For the current forest fire application, two species ($PM_{2.5}$ and PM_{10}) are treated with no chemical transformation.

Subgrid Scale Complex Terrain: The complex terrain module in CALPUFF is based on the approach used in the Complex Terrain Dispersion Model (CTDMPLUS) (Perry et al., 1989).

Table 3-1
Major Features of the CALPUFF Model

- **Source types**
  - Point sources (constant or variable emissions)
  - Line sources (constant emissions)
  - Volume sources (constant or variable emissions)
  - Area sources (constant or variable emissions)

- **Non-steady-state emissions and meteorological conditions**
  - Gridded 3-D fields of meteorological variables (winds, temperature)
  - Spatially-variable fields of mixing height, friction velocity, convective velocity scale, Monin-Obukhov length, precipitation rate
  - Vertically and horizontally-varying turbulence and dispersion rates
  - Time-dependent source and emissions data

- **Efficient sampling functions**
  - Integrated puff formulation
  - Elongated puff (slug) formulation

- **Dispersion coefficient (σ_y, σ_z) options**
  - Direct measurements of σ_v and σ_w
  - Estimated values of σ_v and σ_w based on similarity theory
  - Pasquill-Gifford (PG) dispersion coefficients (rural areas)
  - McElroy-Pooler (MP) dispersion coefficients (urban areas)

- **Vertical wind shear**
  - Puff splitting
  - Differential advection and dispersion

- **Plume rise**
  - Partial penetration
  - Buoyant and momentum rise
  - Stack tip effects
  - Vertical wind shear
  - Building downwash effects

- **Building downwash**
  - Huber-Snyder method
  - Schulman-Scire method

(Continued)

Table 3-1 (Concluded)
Major Features of the CALPUFF Model

- **Subgrid scale complex terrain**
  - Dividing streamline, H_d:
    - Above H_d, puff flows over the hill and experiences altered diffusion rates
    - Below H_d, puff deflects around the hill, splits, and wraps around the hill
- **Interface to the Emissions Production Model (EPM)**
  - Time-varying heat flux and emissions from controlled burns and wildfires
- **Dry Deposition**
  - Gases and particulate matter
  - Three options:
    - Full treatment of space and time variations of deposition with a resistance model
    - User-specified diurnal cycles for each pollutant
    - No dry deposition
- **Overwater and coastal interaction effects**
  - Overwater boundary layer parameters
  - Abrupt change in meteorological conditions, plume dispersion at coastal boundary
  - Plume fumigation
- **Chemical transformation options**
  - Pseudo-first-order chemical mechanism for SO_2, $SO_4^=$, NO_x, HNO_3, and NO_3^- (MESOPUFF II method)
  - User-specified diurnal cycles of transformation rates
  - No chemical conversion
- **Wet Removal**
  - Scavenging coefficient approach
  - Removal rate a function of precipitation intensity and precipitation type
- **Graphical User Interface**
  - Click-and-point model setup and data input
  - Enhanced error checking of model inputs
  - On-line Help files

Plume impingement on subgrid scale hills is evaluated using a dividing streamline (H_d) to determine which pollutant material is deflected around the sides of a hill (below H_d) and which material is advected over the hill (above H_d). Individual puffs are split into up to three sections for these calculations.

Puff Sampling Functions: A set of accurate and computationally efficient puff sampling routines are included in CALPUFF which solve many of the computational difficulties with applying a puff model to near-field releases. For near-field applications during rapidly-varying meteorological conditions, an elongated puff (slug) sampling function is used. An integrated puff approach is used during less demanding conditions. Both techniques reproduce continuous plume results exactly under the appropriate steady state conditions.

Wind Shear Effects: CALPUFF contains an optional puff splitting algorithm that allows vertical wind shear effects across individual puffs to be simulated. Differential rates of dispersion and transport occur on the puffs generated from the original puff, which under some conditions, can substantially increase the effective rate of horizontal growth of the plume.

Building Downwash: The Huber-Snyder and Schulman-Scire downwash models for point sources are both incorporated into CALPUFF. An option is provided to use either model for all stacks, or make the choice on a stack-by-stack and wind sector-by-wind sector basis. Both algorithms have been implemented in such a way as to allow the use of wind direction specific building dimensions.

Overwater and Coastal Interaction Effects: Because the CALMET meteorological model contains both overwater and overland boundary layer algorithms, the effects of water bodies on plume transport, dispersion, and deposition can be simulated with CALPUFF. The puff formulation of CALPUFF is designed to handle spatial changes in meteorological and dispersion conditions, including the abrupt changes which occur at the coastline of a major body of water.

Dispersion Coefficients: Several options are provided in CALPUFF for the computation of dispersion coefficients, including the use of turbulence measurements (σ_v and σ_w), the use of similarity theory to estimate σ_v and σ_w from modeled surface heat and momentum fluxes, or the use of Pasquill-Gifford (PG) or McElroy-Pooler (MP) dispersion coefficients, or dispersion equations based on the Complex Terrain Dispersion Model (CDTM). Options are provided to apply an averaging time correction or surface roughness length adjustments to the PG coefficients.

3.2 Model Options

In the current study, the prescribed fires and wildfires were treated as buoyant area sources. This treatment accounts for the initial size of the fires, and includes buoyant plume rise effects. CALPUFF allows hourly variations of emission parameters and emission rates to be entered into the model. The EPM emission rates for PM_{10} and $PM_{2.5}$ were used in the simulations. Each individual prescribed fire or wildfire was treated as a separate area source. In a separate data base, the Forest Service provide estimates of the size (acreage) and location of each of the fires. These data were merged with the EPM emissions data to create the CALPUFF buoyant area source emissions files (BAEMARB.DAT files). Also, the Forest Service determined that the most appropriate starting time for the fires is 11:00 am (PST). This assumptions synchronizes the EPM output (expressed in time since the start of the fire) with the clock time in CALPUFF. That is, the starting time of each fire is assumed to be 11:00 am on the starting day of the fire indicated in the Forest Service data base. Appendix D contains the emission tables generated by the conversion program that created the area source files, and shows the type, size, starting day, and location of each of the fires.

The technical options selected for the CALPUFF simulations are shown in the Table 3-2. The main options were:

- Pasquill-Gifford dispersion coefficients
- Gaussian vertical distribution in near-field
- ISC-type of terrain adjustment to plume height
- Near-field puffs modeled using integrated puff algorithm
- Transitional plume rise modeled
- Wet deposition modeled
- Dry deposition modeled
- Chemical transformation not modeled
- Scavenging coefficients for PM_{10} and $PM_{2.5}$: $\lambda = 1.\ 10^{-4}\ s^{-1}$ (liquid precipitation), $\lambda = 3.\ x\ 10^{-5}\ s^{-1}$ (frozen precipitation)
- Transition to Heffter dispersion curves when plume size (σ_y) exceed 550 m

The plume rise equations in CALPUFF for buoyant area sources are based on the conservation of mass, momentum, and energy. They are similar to those in Weil (1988) except that the Boussinesq approximation is not applied. The Boussinesq approximation simplifies the plume rise equations by assuming that the plume density is close enough to the ambient density that density variations, other than in the buoyancy term, can be neglected. The plume rise equations are solved numerically using a predictor-corrector scheme. Because of the relatively simple plume penetration

3.2 Model Options

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algorithm in the model, the forest fires plume heights were restricted to be at or less than 500 meters in height, which ensures they are available for fumigation during the diurnal cycle. This is a conservative feature of the modeling.

Table 3-2
Sample CALPUFF control file
(for fall regional scenario, base case emissions)
showing model options.

```
Forest Service - Fall scenario - BASE CASE
October 14-19, 1990
Regional (65 x 53) grid, 20 km grid spacing
---------------- Run title (3 lines) ----------------------------------------

                    CALPUFF MODEL CONTROL FILE
                    --------------------------

------------------------------------------------------------------------------

INPUT GROUP: 1 -- General run control parameters
--------------

     Starting date:   Year (IBYR) -- No default       ! IBYR=  90   !
                     Month (IBMO) -- No default       ! IBMO=  10  !
                       Day (IBDY) -- No default       ! IBDY=  14  !
                      Hour (IBHR) -- No default       ! IBHR=  0  !

     Length of run (hours) (IRLG) -- No default       ! IRLG=  144   !

     Number of chemical species (NSPEC)
                                  Default: 5          ! NSPEC=  2   !

     Number of chemical species
     to be emitted  (NSE)         Default: 3          ! NSE=  2   !

     Flag to stop run after
     SETUP phase (ITEST)          Default: 2          ! ITEST=  2   !
     (Used to allow checking
     of the model inputs, files, etc.)
          ITEST = 1 - STOPS program after SETUP phase
          ITEST = 2 - Continues with execution of program
                      after SETUP

     Meteorological Data Format (METFM)
                                  Default: 1          ! METFM =  1   !

          METFM = 1 - CALMET binary file (CALMET.DAT)
          METFM = 2 - ISC ASCII file (ISCMET.DAT)
          METFM = 3 - AUSPLUME ASCII file (PLMMET.DAT)

     Averaging Time (minutes) (AVET)
                                  Default: 60.0       ! AVET = 60. !
     PG sigma-y is adjusted by the equation
     (AVET/60.0)**0.2

!END!

------------------------------------------------------------------------------

INPUT GROUP: 2 -- Technical options
--------------

     Vertical distribution used in the
     near field (MGAUSS)          Default: 1          ! MGAUSS =  1   !
        0 = uniform
        1 = Gaussian

     Terrain adjustment method
     (MCTADJ)                     Default: 1          ! MCTADJ =  1   !
        0 = no adjustment
        1 = ISC-type of terrain adjustment
        2 = simple, CALPUFF-type of terrain
            adjustment
```

Table 3-2 (Continued)
Sample CALPUFF control file
(for fall regional scenario, base case emissions)
showing model options.

```
Subgrid-scale complex terrain
flag (MCTSG)                          Default: 0     ! MCTSG =  0  !
   0 = not modeled
   1 = modeled

Near-field puffs modeled as
elongated 0 (MSLUG)                   Default: 1     ! MSLUG =  0  !
   0 = no
   1 = yes (slug model used)

Transitional plume rise modeled ?
(MTRANS)                              Default: 1     ! MTRANS =  1  !
   0 = no  (i.e., final rise only)
   1 = yes (i.e., transitional rise computed)

Stack tip downwash? (MTIP)            Default: 1     ! MTIP =  0  !
   0 = no  (i.e., no stack tip downwash)
   1 = yes (i.e., use stack tip downwash)

Vertical wind shear modeled above
stack top? (MSHEAR)                   Default: 0     ! MSHEAR =  0  !
   0 = no  (i.e., vertical wind shear not modeled)
   1 = yes (i.e., vertical wind shear modeled)

Puff splitting allowed? (MSPLIT)      Default: 0     ! MSPLIT = 0 !
   0 = no (i.e., puffs not split)
   1 = yes (i.e., puffs are split)

Chemical mechanism flag (MCHEM)       Default: 1     ! MCHEM =  0  !
   0 = chemical transformation not
       modeled
   1 = transformation rates computed
       internally (MESOPUFF II scheme)
   2 = user-specified transformation
       rates used

Wet removal modeled ? (MWET)          Default: 1     ! MWET =  1  !
   0 = no
   1 = yes

Dry deposition modeled ? (MDRY)       Default: 1     ! MDRY =  1  !
   0 = no
   1 = yes
   (dry deposition method specified
    for each species in Input Group 3)

Method used to compute dispersion
coefficients (MDISP)                  Default: 4     ! MDISP =  4  !

   1 = dispersion coefficients computed from values of
       sigma v, sigma w read from SIGMA.DAT file
   2 = dispersion coefficients sigma v, sigma w computed
       internally from micrometeorological variables (u*, w*, L, etc.)
   3 = PG dispersion coefficients for RURAL areas (computed using
       the ISCST multi-segment approximation) and MP coeffients in
       urban areas
   4 = same as 3 except PG coefficients computed using
       the MESOPUFF II eqns.
   5 = CTDM sigmas used for stable and neutral conditions.
       For unstable conditions, sigmas are computed as in
       MDISP = 1, described above.  MDISP = 5 assumes that
       sigma v, sigma w are read from SIGMA.DAT file
```

Table 3-2 (Continued)
Sample CALPUFF control file
(for fall regional scenario, base case emissions)
showing model options.

```
PG sigma-y,z adj. for roughness?        Default: 0    ! MROUGH =  0  !
(MROUGH)
   0 = no
   1 = yes

Partial plume penetration of            Default: 0    ! MPARTL =  1  !
elevated inversion?
(MPARTL)
   0 = no
   1 = yes

Test options specified to see if
they conform to regulatory
values? (MREG)                        Default: 0   ! MREG =  0   !

   0 = NO checks are made
   1 = Technical options must conform to USEPA values for
       short-range modeling (e.g. ISC-type applications)
   2 = Technical options must conform to USEPA values for
       long-range modeling (e.g. visibility-type applications)
   3 = Other constraints

!END!

-------------------------------------------------------------------------------

INPUT GROUP: 3 -- Species list
--------------

The following species are modeled:

! CSPEC = PM10 !          !END!
! CSPEC = PM25 !          !END!

                                                  Dry
SPECIES        MODELED          EMITTED        DEPOSITED
 NAME       (0=NO, 1=YES)    (0=NO, 1=YES)  (0=NO,
                                              1=COMPUTED-GAS
                                              2=COMPUTED-PARTICLE
                                              3=USER-SPECIFIED)
! PM10=            1 ,              1 ,          2    !
! PM25=            1 ,              1 ,          2    !

!END!

-------------------------------------------------------------------------------

INPUT GROUP: 4 -- Grid control parameters
--------------

METEOROLOGICAL grid:

          No. X grid cells (NX)      No default     ! NX =  65   !
          No. Y grid cells (NY)      No default     ! NY =  53   !
       No. vertical layers (NZ)      No default     ! NZ =  11   !

         Grid spacing (DGRIDKM)      No default     ! DGRIDKM = 20. !
                                     Units: km
```

Table 3-2 (Continued)
Sample CALPUFF control file
(for fall regional scenario, base case emissions)
showing model options.

```
            Cell face heights
               (ZFACE(nz+1))        No defaults
                                    Units: m
I ZFACE = 0., 20., 80., 120., 280., 520., 1080., 1400., 1800., 2200.,
          3000., 4000. I

         Reference Coordinates
       of SOUTHWEST corner of
            grid POINT(1, 1):

        X coordinate (XORIGKM)      No default     ! XORIGKM = -700. !
        Y coordinate (YORIGKM)      No default     ! YORIGKM = 5000. !
                                   Units: km

            UTM zone (IUTMZN)       No default     ! IUTMZN =  11  !

   Reference coordinates of CENTER
       of the domain (used in the
    calculation of solar elevation
                         angles)

       Latitude  (deg.) (XLAT)      No default     ! XLAT  = 45.5  !
      Longitude (deg.) (XLONG)      No default     ! XLONG = 117.  !
        Time zone        (XTZ)      No default     ! XTZ   = 8.  !
   (PST=8, MST=7, CST=6, EST=5)
```

Computational grid:

The computational grid is identical to or a subset of the MET. grid. The lower left (LL) corner of the computational grid is at grid point (IBCOMP, JBCOMP) of the MET. grid. The upper right (UR) corner of the computational grid is at grid point (IECOMP, JECOMP) of the MET. grid. The grid spacing of the computational grid is the same as the MET. grid.

```
X index of LL corner (IBCOMP)       No default     ! IBCOMP =  1   !
        (1 <= IBCOMP <= NX)

Y index of LL corner (JBCOMP)       No default     ! JBCOMP =  1   !
        (1 <= JBCOMP <= NY)

X index of UR corner (IECOMP)       No default     ! IECOMP =  65   !
        (1 <= IECOMP <= NX)

Y index of UR corner (JECOMP)       No default     ! JECOMP =  53   !
        (1 <= JECOMP <= NY)
```

SAMPLING GRID (GRIDDED RECEPTORS):

The lower left (LL) corner of the sampling grid is at grid point (IBSAMP, JBSAMP) of the MET. grid. The upper right (UR) corner of the sampling grid is at grid point (IESAMP, JESAMP) of the MET. grid. The sampling grid must be identical to or a subset of the computational grid. It may be a nested grid inside the computational grid. The grid spacing of the sampling grid is DGRIDKM/MESHDN.

```
Logical flag indicating if gridded
receptors are used (LSAMP)          Default: T     ! LSAMP = T !
(T=yes, F=no)

X index of LL corner (IBSAMP)       No default     ! IBSAMP =  1   !
 (IBCOMP <= IBSAMP <= IECOMP)
```

Table 3-2 (Continued)
Sample CALPUFF control file
(for fall regional scenario, base case emissions)
showing model options.

```
      Y index of LL corner (JBSAMP)      No default      ! JBSAMP =  1   !
       (JBCOMP <= JBSAMP <= JECOMP)

      X index of UR corner (IESAMP)      No default      ! IESAMP =  65  !
       (IBCOMP <= IESAMP <= IECOMP)

      Y index of UR corner (JESAMP)      No default      ! JESAMP =  53  !
       (JBCOMP <= JESAMP <= JECOMP)

      Nesting factor of the sampling
       grid (MESHDN)                     No default      ! MESHDN =  1   !
       (MESHDN is an integer >= 1)

!END!

-------------------------------------------------------------------------------

INPUT GROUP: 5 -- Output Options
--------------

                                    *                          *
   FILE                        DEFAULT VALUE            VALUE THIS RUN
   ----                        -------------            --------------

  Concentrations (ICON)            1                     !   ICON =  1   !
  Dry Fluxes (IDRY)                1                     !   IDRY =  0   !
  Wet Fluxes (IWET)                1                     !   IWET =  0   !
  Relative Humidity (IVIS)         1                     !   IVIS =  1   !
   (relative humidity file is
    required for visibility
    analysis)

  *
   0 = Do not create file, 1 = create file

   LINE PRINTER OUTPUT OPTIONS:

      Print concentrations (ICPRT)    Default: 0         ! ICPRT =  1   !
      Print dry fluxes (IDPRT)        Default: 0         ! IDPRT =  0   !
      Print wet fluxes (IWPRT)        Default: 0         ! IWPRT =  0   !
      (0 = Do not print, 1 = Print)

      Concentration print interval
      (ICFRQ) in hours                Default: 1         !  ICFRQ =  12  !
      Dry flux print interval
      (IDFRQ) in hours                Default: 1         !  IDFRQ =  1   !
      Wet flux print interval
      (IWFRQ) in hours                Default: 1         !  IWFRQ =  1   !

      Messages tracking progress of   Default: 1         !  IMESG =  0   !
      run written to the screen ?
      (IMESG) -- 0=no, 1=yes

    SPECIES LIST FOR OUTPUT OPTIONS

            ------ CONCENTRATIONS -------   --------- DRY FLUXES ----------   -------- WET FLUXES --------
SPECIES
 NAME        PRINTED ?     SAVED ON DISK ?   PRINTED ?     SAVED ON DISK ?   PRINTED ?     SAVED ON DISK ?
-------     ---------------------------------------------------------------------------------------------
! PM10=        1 ,            1 ,             0 ,            0 ,             0 ,            0   !
! PM25=        1 ,            1 ,             0 ,            0 ,             0 ,            0   !
```

Table 2-2 (continued)
Sample CARDS control file
(for full regional system, some area overlays
should avoid options.

```
( index of LL corner (XLLMN)      no default     ( xLLMN = 1  )
(ICORN <= XRANG <= xCOLN)

( index of UR corner (IZLMN)      no default     ( IZLMN = 65 )
(ICORN <= IZRANG <= iICMN)

( index of UR corner (xZLMN)      no default     ( xZRANG = 53 )
(ICORN <= iZRANG <= xICORN)

Rotating factor: at the equator
grid (RZCOSM)                     no default     ( RZCOSM = 1 )
(RZ.GMOD is an integer >= 1)

IEOC:

*****************************************************************

CARD CARDS 3 -- Output Options
------------------------------

*
FILE                    DEFAULT VALUE                VALUE THIS RUN
---                     -------------                --------------

Conservations (ICON)    1                            ( ICON = 1  )
Dry Fluxes (ldRY)       1                            ( IDRY = 1  )
Wet Fluxes (iIWET)      1                            ( IWET = 0  )
Relative Humidity (IVIX)  1                          ( IVIX = 1  )
(relative humidity file is
required for visibility
analysis)

*
0 = Do not create file, 1 = create file

LINE PRINTER OUTPUT OPTIONS

Print conservations (ICPRT)  Default: 0          ( ICPRT = 1  )
Print dry fluxes (IDPRT)     Default: 0          ( IDPRT = 0  )
Print wet fluxes (iIWPRT)    Default: 0          ( IWPRT = 0  )
(0 = Do not print, 1 = Print)

Conservation print interval
(ICPRD) in hours             Default: 1          ( ICPRD = 12 )
Dry flux print interval
(IDPRD) in hours             Default: 3          ( IDPRD = 1  )
Wet flux print interval
(IWPRD) in hours             Default: 1          ( IWPRD = 1  )

Maximum vertical profiles at  Default: 0         ( IMPRO = 0  )
run written to the printer
(IMPRO) <= 6000, 1=yes

SPECIFICATION FOR OUTPUT OPTIONS

------ CONSERVATIONS ------  ------- DRY FLUXES -------  ------- WET FLUXES -------
OPTIONS
BANK
-----
( PRINT=  )  BANKED ON DISK ?  PRINTED ?  BANKED ON DISK ?  PRINTED ?  BANKED ON DISK ?
-----------------------------------------------------------------------------------
( PRINT=  )  1 ,  1 ,  0 ,  0 ,  0 ,  0 ,
( PRINT=  )  1 ,  1 ,  0 ,  0 ,  0 ,  0 ,
```

Table 3-2 (Continued)
Sample CALPUFF control file
(for fall regional scenario, base case emissions)
showing model options.

```
OPTIONS FOR PRINTING "DEBUG" QUANTITIES (much output)

  Logical for debug output
  (LDEBUG)                                Default: F     ! LDEBUG = F !

  Number of puffs to track
  (NPFDEB)                                Default: 1     ! NPFDEB =  1  !

  Met. period to start output
  (NN1)                                   Default: 1     ! NN1 =  1   !

  Met. period to end output
  (NN2)                                   Default: 10    ! NN2 =  10  !

!END!

-------------------------------------------------------------------------------

INPUT GROUP: 6a, 6b, & 6c -- Subgrid scale complex terrain inputs
------------------------

---------------
Subgroup (6a)
---------------
      Number of terrain features (NHILL)      Default: 0     ! NHILL =  0   !

      Number of special complex terrain
      receptors  (NCTREC)                     Default: 0     ! NCTREC =  0   !

      Terrain data for CTSG hills input in
      CTDM format ? (MHILL)                   No Default     ! MHILL =  1   !
      1 = Hill data created by CTDM
          processors & read from HILL.DAT
          file
      2 = Hill data created by OPTHILL &
          input below in Subgroup (6b)

      Factor to convert horizontal dimensions  Default: 1.0   !XHILL2M = 1. !
      to meters (MHILL=1)

      Factor to convert vertical dimensions    Default: 1.0   !ZHILL2M = 1. !
      to meters (MHILL=1)

! END !

---------------
Subgroup (6b)
---------------

                    1 **
    HILL information

HILL    XC     YC    THETAH    ZGRID    RELIEF    EXPO 1    EXPO 2    SCALE 1    SCALE 2    AMAX1    AMAX2
 NO.   (km)   (km)   (deg.)     (m)       (m)       (m)       (m)        (m)        (m)       (m)      (m)
----   ----   ----   ------    -----    ------    ------    ------    -------    -------    -----    -----

(not used in this run)

---------------
Subgroup (6c)
---------------
```

BLM Library
Denver Federal Center
Bldg. 85, OC-521
P.O. Box 25047
Denver, CO 80225

BLM Library
Denver Federal Center
Bldg. 85, OC-521
P.O. Box 25047
Denver, CO 80225

Table 3-2 (Continued)
Sample CALPUFF control file
(for fall regional scenario, base case emissions)
showing model options.

```
COMPLEX TERRAIN RECEPTOR INFORMATION

          XRCT       YRCT       ZRCT        XHH
          (km)       (km)       (m)
         ------     -----     ------       ----
         (not used in this run)
 ------------------
 1
     Description of Complex Terrain Variables:
          XC, YC  = Coordinates of center of hill
          THETAH  = Orientation of major axis of hill (clockwise from
                    North)
          ZGRID   = Height of the  0  of the grid above mean sea
                    level
          RELIEF  = Height of the crest of the hill above the grid elevation
          EXPO 1  = Hill-shape exponent for the major axis
          EXPO 2  = Hill-shape exponent for the major axis
          SCALE 1 = Horizontal length scale along the major axis
          SCALE 2 = Horizontal length scale along the minor axis
          AMAX    = Maximum allowed axis length for the major axis
          BMAX    = Maximum allowed axis length for the major axis

          XRCT, YRCT = Coordinates of the complex terrain receptors
          ZRCT    = Height of the ground (MSL) at the complex terrain
                    Receptor
          XHH     = Hill number associated with each complex terrain receptor
                    (NOTE: MUST BE ENTERED AS A REAL NUMBER)

   **
     NOTE: DATA for each hill and CTSG receptor are treated as a separate
           input subgroup and therefore must end with an input group terminator.

 ---------------------------------------------------------------------------

 INPUT GROUP: 7 -- Chemical parameters for dry deposition of gases
 --------------

 SPECIES     DIFFUSIVITY     ALPHA STAR     REACTIVITY    MESOPHYLL RESISTANCE     HENRY'S LAW COEFFICIENT
  NAME        (cm**2/s)                                         (s/cm)                (dimensionless)
 -------     -----------     ----------     ----------    --------------------     ----------------------

 (not used in this run)

 !END!

 ---------------------------------------------------------------------------

 INPUT GROUP: 8 -- Size parameters for dry deposition of particles
 --------------

 SPECIES      GEOMETRIC MASS MEAN        GEOMETRIC STANDARD
  NAME             DIAMETER                  DEVIATION
                   (microns)                 (microns)
 -------      -------------------        -----------------
 ! PM10=              2.0,                       2.   !
 ! PM25=              1.5,                       2.   !

 !END!

 ---------------------------------------------------------------------------
```

Table 3-2 (Continued)
Sample CALPUFF control file
(for fall regional scenario, base case emissions)
showing model options.

```
INPUT GROUP: 9 -- Miscellaneous dry deposition parameters
--------------

     Reference cuticle resistance   (RCUTR)  (s/cm)   !  RCUTR = 30. !
     Reference ground resistance    (RGR)    (s/cm)   !    RGR = 5. !
     Reference pollutant reactivity (REACTR)          ! REACTR = 8. !

     Vegetation state in unirrigated areas (IVEG)     !   IVEG =  1   !
        IVEG=1 for active and unstressed vegetation
        IVEG=2 for active and stressed vegetation
        IVEG=3 for inactive vegetation

!END!

-------------------------------------------------------------------------------

INPUT GROUP: 10 -- Wet Deposition Parameters
---------------

                    Scavenging Coefficient -- Units: (sec)**(-1)

     Pollutant      Liquid Precip.       Frozen Precip.
     ---------      --------------       --------------
    !  PM10=            1.0E-04,             3.0E-05 !
    !  PM25=            1.0E-04,             3.0E-05 !

!END!

-------------------------------------------------------------------------------

INPUT GROUP: 11 -- Chemistry Parameters
---------------

     Ozone data input option (MOZ)     Default: 1          ! MOZ =  0   !
     (Used only if MCHEM = 1)
        0 = use a constant background ozone value
        1 = read hourly ozone concentrations from
            the OZONE.DAT data file

     Background ozone concentration
     (BCKO3) in ppb                    Default: 80.        ! BCKO3 = 80. !
     (Used only if MCHEM = 1 and
      MOZ = 0 or (MOZ = 1 and all hourly
      O3 data missing)

     Background ammonia concentration
     (BCKNH3) in ppb                   Default: 10.        ! BCKNH3 = 10. !

     Nighttime SO2 loss rate (RNITE1)
     in percent/hour                   Default: 0.2        ! RNITE1 = 0.2 !

     Nighttime NOx loss rate (RNITE2)
     in percent/hour                   Default: 2.0        ! RNITE2 = 2. !

     Nighttime HNO3 formation rate (RNITE3)
     in percent/hour                   Default: 2.0        ! RNITE3 = 2. !

!END!
```

Table 3-2 (Continued)
Sample CALPUFF control file
(for fall regional scenario, base case emissions)
showing model options.

```
------------------------------------------------------------------------------

INPUT GROUP: 12 -- Misc. Dispersion and Computational Parameters
----------------

     Horizontal size of puff (m) beyond which
     time-dependent dispersion equations (Heffter)
     are used to determine sigma-y and
     sigma-z (SYTDEP)                        Default: 550.   ! SYTDEP = 5.5E02 !

     Switch for using Heffter equation for sigma z
     as above (0 = Not use Heffter; 1 = use Heffter
     (MHFTSZ)                                Default: 1      ! MHFTSZ =  1   !

     Stability class used to determine plume
     growth rates for puffs above the boundary
     layer (JSUP)                            Default: 5      ! JSUP =  5   !

     Vertical dispersion constant for stable
     conditions (k1 in Eqn. 2.7-3)  (CONK1)  Default: 0.01   ! CONK1 = 0.01 !

     Vertical dispersion constant for neutral/
     unstable conditions (k2 in Eqn. 2.7-4)
     (CONK2)                                 Default: 0.1    ! CONK2 = 0.1 !

     Range of land use categories for which
     urban dispersion is assumed
     (IURB1, IURB2)                          Default: 10     ! IURB1 =  10  !
                                                      19     ! IURB2 =  19  !

     Maximum length of a slug (met. grid units)
     (XMXLEN)                                Default: 1.0    ! XMXLEN = 1. !

     Maximum travel distance of a puff/slug (in
     grid units) during one sampling step
     (XSAMLEN)                               Default: 5.0    ! XSAMLEN = 5. !

     Maximum Number of slug/puff release from
     one source during one time step
     (MXNEW)                                 Default: 99     ! MXNEW =  99   !

     Maximum Number of sampling steps for
     one puff/slug during one time step
     (MXSAM)                                 Default: 5      ! MXSAM =  5   !

     Minimum sigma y for a new puff/slug (m)
     (SYMIN)                                 Default: 0.01   ! SYMIN = 0.01  !

     Minimum sigma z for a new puff/slug (m)
     (SZMIN)                                 Default: 0.01   ! SZMIN = 0.01  !

     Minimum turbulence sigma-v (m/s)
     (SVMIN)                                 Default: 0.50   ! SVMIN = 0.5  !

     Minimum turbulence sigma-w (m/s)
     (SWMIN)                                 Default: 0.016  ! SWMIN = 0.016  !

     Minimum wind speed (m/s) allowed for
     non-calm conditions. Also used as minimum
     speed returned when using power-law
     extrapolation toward surface
     (WSCALM)                                Default: 1.0    ! WSCALM = 1. !
```

Table 3-2 (Continued)
Simple CALPUFF control file
(for full Fortran/Compaq, Lahey case sensitive)
showing model options.

Input group: 12 -- Mixing, Dispersion and Chemistry Parameters
---

! Vertical size of puff (m) beyond which
plume-segment dispersion coefficients (sigmaz)
are used in determining sigmay and
sigmaz (SYPUFF)

Default: 300. ! SYPUF = 1.5SZPU !

Switch for using Gaussian puff dispersion in place of
an upwind (0 = not use Gaussian; 1 = use Gaussian
puff)

Default: 1 ! MGAUSS = 1 !

Stability class used to determine plume
growth rates for puffs above the boundary
layer (SGLOP)

Default: 5 ! SLOP = 5 !

Vertical dispersion constant for stable
conditions (kz in Tech. Ref.) (CONSTZ)

Default: 0.01 ! CONSTZ = 0.01 !

Vertical dispersion constant for convective/
unstable conditions (kz in Tech. Ref.)
(CONSTZ)

Default: 0.1 ! CONSTC = 0.1 !

Range of land use categories for which
urban dispersion is assumed
(IURB1, IURB2)

Default: 30 ! IURB1 = 30 !
19 ! IURB2 = 19 !

Maximum length of a slug (met. grid units)
(XMAXZ)

Default: 4.0 ! XMAXZ = 4.0 !

Maximum travel distance of a puff/slug (in
grid units) during one sampling step
(XMINZ)

Default: 2.0 ! XMINZ = 2.0 !

Maximum random orientation of puff/slug from
the source during one time step
(MTAUY)

Default: 60 ! MTAUY = 60 !

Maximum number of sampling steps for
one puff/slug during one time step
(MSLAG)

Default: 5 ! MSLAG = 5 !

Minimum sigmy (m) a puff/slug can have
(SYMIN)

Default: 0.01 ! SYMIN = 0.01 !

Minimum sigmz (m) a puff/slug can have
(SZMIN)

Default: 0.01 ! SZMIN = 0.01 !

Minimum turbulence sigmav (m/s)
(SVMIN)

Default: 0.50 ! SVMIN = 0.5 !

Minimum turbulence sigmaw (m/s)
(SWMIN)

Default: 0.020 ! SWMIN = 0.020 !

Minimum wind speed (m/s) allowed for
non-calm conditions. Also used as minimum
speed returned when using power-law
extrapolation toward surface
(SPECMIN)

Default: 1.0 ! SPECMIN = 1.0 !

Table 3-2 (Continued)
Sample CALPUFF control file
(for fall regional scenario, base case emissions)
showing model options.

```
Maximum mixing height (m)
(XMAXZI)                                    Default: 3000.  !  XMAXZI = 2500. !

Minimum mixing height (m)
(XMINZI)                                    Default: 20.    !  XMINZI = 20. !

Default wind speed profile power-law
exponents for stabilities 1-6
(PLXO(6))                          Default   : ISC RURAL values
                                   ISC RURAL : .07, .07, .10, .15, .35, .55
                                   ISC URBAN : .15, .15, .20, .25, .30, .30

                          Stability Class :  A     B     C     D     E     F
                                            ---   ---   ---   ---   ---   ---
                                   ! PLXO = 0.07, 0.07, 0.10, 0.15, 0.35, 0.55 !

Default potential temperature gradient
for stable classes E, F (degK/m)
(PTGO(2))                                          Default: 0.020, 0.035
                                                   ! PTGO = 0.020,   0.035 !

Default plume path coefficients for
each stability class (used when option
for partial plume height terrain adjustment
is selected -- MCTADJ=3)
(PPC(6))                   Stability Class :  A     B     C     D     E     F
                              Default  PPC : .50,  .50,  .50,  .50,  .35,  .35
                                            ---   ---   ---   ---   ---   ---
                                   !  PPC = 0.50, 0.50, 0.50, 0.50, 0.35, 0.35 !

Slug-to-puff transition criterion factor
equal to sigma-y/length of slug
(SL2PF)                                Default: 100        ! sl2pf = 100. !

!END!

-------------------------------------------------------------------------------

INPUT GROUPS: 13a, 13b, 13c -- Point source parameters
--------------------------

---------------
Subgroup (13a)
---------------

     Number of point sources with
     constant emission parameters   (NPT1)  No default  !  NPT1 =  0  !

     Number of point sources with
     variable emission parameters   (NPT2)  No default  !  NPT2 =  0  !

     (If NPT2 > 0, the variable point
     source emissions are read from
     the file: PTEMARB.DAT)

!END!

---------------
Subgroup (13b)
---------------

          POINT SOURCE DATA FOR SOURCES WITH CONSTANT EMISSION PARAMETERS[a]
          ----------------------------------------------------------------
```

Table 3-2 (Continued)
Sample CALPUFF control file
(for fall regional scenario, base case emissions)
showing model options.

Source No.	X UTM Coordinate (km)	Y UTM Coordinate (km)	Stack Height (m)	Base Elevation (m)	Stack Diameter (m)	Exit Velocity (m/s)	Exit Temp. (deg. K)	Bldg. Downwash[b]	Emission Rates (g/s)[c]

(not used in this run)

---

[a] Data for each source are treated as a separate input subgroup and therefore must end with an input group terminator.

[b] 0. = No building downwash modeled, 1. = downwash modeled
NOTE: must be entered as a REAL number (i.e., with decimal point)

[c] 1 emission rates must be entered (one for every pollutant).
Enter emission rate of zero for secondary pollutants.

Subgroup (13c)

BUILDING DIMENSION DATA FOR SOURCES SUBJECT TO DOWNWASH

Source No.	Effective building width and height (in meters) every 10 degrees

(not used in this run)

INPUT GROUPS: 14a, 14b, 14c -- Area source parameters

Subgroup (14a)

Number of polygon area sources with constant emission parameters (NAR1) No default ! NAR1 = 0 !

Number of buoyant polygon area sources with variable location and emission parameters (NAR2) No default ! NAR2 = 754 !
(If NAR2 > 0, ALL variable area source data are read from the file: BAEMARB.DAT)

!END!

Subgroup (14b)

AREA SOURCE DATA FOR SOURCES WITH CONSTANT EMISSION PARAMETERS[a]

Source No.	Effect. Height (m)	Base Elevation (m)	Initial Sigma z (m)	Emission Rates (g/s/m^2)[b]

(not used in this run)

Table 3-2 (Continued)
Sample CALPUFF control file
(for fall regional scenario, base case emissions)
showing model options.

```
--------
    a
     Data for each source are treated as a separate input subgroup
     and therefore must end with an input group terminator.

    b
      1  emission rates must be entered (one for every pollutant).
      Enter emission rate of zero for secondary pollutants.

---------------
Subgroup (14c)
---------------

          COORDINATES (UTM-km) FOR EACH VERTEX(4) OF EACH POLYGON
          -------------------------------------------------------
Source                                                          a
 No.      Ordered list of X followed by list of Y, grouped by source
------    ---------------------------------------------------------
(not used in this run)

--------
    a
     Data for each source are treated as a separate input subgroup
     and therefore must end with an input group terminator.


-------------------------------------------------------------------------------

INPUT GROUPS: 15a, 15b -- Line source parameters
---------------------

---------------
Subgroup (15a)
---------------

     Number of buoyant line sources (NLINES)   No default   ! NLINES =  0   !


     Maximum number of segments used to model
     each line (MXNSEG)                        Default: 7   ! MXNSEG =  7   !

     The following variables are required only if NLINES > 0.  They are
     used in the buoyant line source plume rise calculatins.

        Average line source length (XL)          No default   ! XL = 0. !
                                                (in meters)

        Average height of line source height (HBL)  No default   ! HBL = 0. !
                                                 (in meters)

        Average building width (WBL)             No default   ! WBL = 0. !
                                                 (in meters)

        Average line source width (WML)          No default   ! WML = 0. !
                                                 (in meters)

        Average separation between buildings (DXL)  No default   ! DXL = 0. !
                                                 (in meters)

        Average buoyancy parameter (FPRIMEL)     No default   ! FPRIMEL = 0. !
                                                 (in m**4/s**3)

!END!

---------------
```

Table 3-2 (Continued)
Sample CALPUFF control file
(for fall regional scenario, base case emissions)
showing model options.

Subgroup (15b)

BUOYANT LINE SOURCE DATA

Source No.	Beg. X Coordinate (km)	Beg. Y Coordinate (km)	End. X Coordinate (km)	End. Y Coordinate (km)	Release Height (m)	Base Elevation (m)	Emission Rates (g/s)[a]

(not used in this run)

[a] Data for each source are treated as a separate input subgroup and therefore must end with an input group terminator.

[b] 1 emission rates must be entered (one for every pollutant). Enter emission rate of zero for secondary pollutants.

INPUT GROUPS: 16a & 16b -- Volume source parameters

Subgroup (16a)

Number of volume sources with constant emission parameters (NVL1) No default ! NVL1 = 0 !

Gridded volume source data used ? (IGRDVL) No default ! IGRDVL = 0 !
0 = no
1 = yes (gridded volume source emissions read from the file: VOLEM.DAT)

The following parameters apply to the data in the gridded volume source emissions file (VOLEM.DAT)

- Effective height of emissions (VEFFHT) in meters No default ! VEFFHT = 0. !
- Initial sigma y (VSIGYI) in meters No default ! VSIGYI = 0. !
- Initial sigma z (VSIGZI) in meters No default ! VSIGZI = 0. !

!END!

Subgroup (16b)

Table 3-2 (Continued)
Sample CALPUFF control file
(for fall regional scenario, base case emissions)
showing model options.

VOLUME SOURCE DATA -- CONSTANT EMISSION PARAMETERS[a]

X UTM Coordinate (km)	Y UTM Coordinate (km)	Effect. Height (m)	Base Elevation (m)	Initial Sigma y (m)	Initial Sigma z (m)	Emission Rates[b] (g/s)
(not used in this run)						

[a] Data for each source are treated as a separate input subgroup and therefore must end with an input group terminator.

[b] 2 emission rates must be entered (one for every pollutant). Enter emission rate of zero for secondary pollutants.

INPUT GROUPS: 17a & 17b -- Non-gridded (discrete) receptor information

Subgroup (17a)

Number of non-gridded receptors (NREC) No default ! NREC = 0 !

!END!

Subgroup (17b)

NON-GRIDDED (DISCRETE) RECEPTOR DATA[a]

Receptor No.	X UTM Coordinate (km)	Y UTM Coordinate (km)	Ground Elevation (m)
(not used in this run)			

[a] Data for each receptor are treated as a separate input subgroup and therefore must end with an input group terminator.

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4. SUMMARY OF MODELING RESULTS

A complete set of daily contour plots of 24-hour average regional PM_{10} and $PM_{2.5}$ concentrations predicted by the wildfire and prescribed burn simulations are provided in Appendix E. The contour plots of PM_{10} concentrations for each of the prescribed burn emissions scenarios with the highest emissions (i.e., base+1500% case) are provided in Figures 4-1 through 4-3 for the last three days of the early spring episode, Figures 4-4 through 4-9 for five days in the late spring episode, Figures 4-10 through 4-17 for eight days in the summer wildfire episode, and Figures 4-18 through 4-23 for the fall controlled burn episode.

Twenty-four hour average values above 150 $\mu g/m^3$ for PM_{10} and above 60 $\mu g/m^3$ for $PM_{2.5}$ are indicated in the contour plots with a heavy dark line. The wildfire scenarios produce the only simulations with predicted concentrations above these threshold values. The predicted concentrations for the controlled burn scenarios are substantially lower than the wildfire scenarios for several reasons: (1) the acreage burned with the prescribed fires are generally lower; (2) dispersion conditions during the spring and fall prescribed burn episodes are better, and (3) there are larger numbers and a larger spatial distribution of prescribed fires, resulting in a better dilution of the fire emissions. Although a compensating factor is the larger buoyancy and potentially higher plume rise of the wildfire plumes compared to the smaller prescribed burn plumes, the model options were selected in such a way as to keep all the fire plumes within the daytime mixed layer. The wildfire plumes may start out higher, but they eventually mix to the ground and result in higher ground level concentrations of PM_{10} and $PM_{2.5}$.

The number of grid cells with 24-hour average concentrations above the threshold values are shown in Tables 4-1 through 4-6. There were no exceedances of the threshold values for any of the prescribed burn simulations. Wildfire scenario #1 produced the largest number of grid points exceeding the $PM_{2.5}$ threshold (443 for the 100% emissions case). Wildfire scenario #2 has the greatest number of exceedances of the PM_{10} threshold value (190 for the 100% emissions case). Each of the nine wildfire scenarios had at least some exceedances of the threshold value (e.g., 83, 3, and 3, for the 25% $PM_{2.5}$ emissions cases for wildfire scenarios 1-3, respectively, and 19, 4, and 3 for the PM_{10} cases).

In the fine-scale simulations, two emission scenarios (base case, base case + 1500%) were evaluated for the early spring, late spring, and fall episodes. These simulations bracket the range of emissions for each of the episodes. The summer episode was simulated using wildfire scenario #1 with 100% of base case emissions and 25% of base case emissions to cover the range of emissions estimates.

Contour plots for the highest emission scenario (base+1500% for prescribed fires, 100% of base for the wildfires) fine-scale simulations are presented in Figures 4-18 through 4-25. Because emissions outside the modeling domain do not contribute to concentration estimates on the grid, the fine-scale simulations reflect the impacts of only fires within the domain. Appendix G contains a complete set of contour plots for each of the fine-scale simulations. Because there are a few periods with no active fires within the domain, the predicted concentrations show no impacts for some days.

As with the regional simulations, the number of cells in the fine-scale domain that exceeded the 24-hour PM_{10} and $PM_{2.5}$ thresholds defined above were computed for each simulated day. The results indicate no exceedances of the thresholds for any of the prescribed burn or wildfire emission scenarios. This analysis reflects only contributions of fires within the domain. Thus, the fine-scale grid concentrations do not include the impact of prescribed fires or wildfires outside the fine-scale computational domain (200 km x 200 km).

Two important assumptions likely to affect the concentration estimates should be mentioned. The first is the assumed start time of the fires (11:00 am). This start time results in the bulk of the emissions being released during the unstable daytime hours, when vertical mixing is enhanced and the plume is likely to be diluted relatively quickly. Fires that are active during the stable nighttime hours have the potential to produce higher ground-level impacts due to lower plume heights and less favorable dispersion conditions. A second assumption is that the size of the area source is equal to the acreage burned. This may tend to overestimate the near-field dilution of pollutants, especially in the early part of the fire's history. Both of these assumptions are based on the best information available to the Forest Service. However, additional sensitivity tests to quantify the sensitivity of the modeling results to these assumptions are recommended.

A separate report (Richards et al., 1995) contains a summary of background light extinction in the modeling domain during each of the episode days. The data used to estimate the background light extinction values include SAMSON surface observational data, Aerometric Information Retrieval System (AIRS) PM_{10} concentration data, Pacific Northwest Regional Visibility Experiment Using Natural Tracers (PREVENT) data, and Interagency Monitoring of Protected Visual Environments (IMPROVE) data. The CALPOST processor contains an algorithm to estimate light-extinction coefficients (b_{ext}) based on the predicted concentrations of particulate matter. The contribution of particulate matter to b_{ext} is a function of the size distribution of the particulate matter. The extinction efficiency is defined such that:

$$b_{ext} = E_{2.5}\, \chi_{2.5} \qquad (4\text{-}1)$$

where $E_{2.5}$ is the extinction efficiency (m^2/g) for $PM_{2.5}$, $\chi_{2.5}$ is the concentration ($\mu g/m^3$) of $PM_{2.5}$, and

b_{ext} is in units of inverse megameters (Mm^{-1}). For a dry aerosol, Waggoner et al. (1981) suggest $E_{2.5}$ is 3.1 ± 0.2 m^2/g, and White et al. (1994) indicate $E_{2.5}$ is between 2.8-3.1 m^2/g. Richards and Saydah (1995) recommend a value of 3.0 m^2/g for $E_{2.5}$. For PM_{10}, the extinction efficiency (E_{10}) is in the range of 1-2 m^2/g, although its value depends heavily on the relative amounts of coarse vs. fine particle mass. Fine particles (less than 2.5 μm diameter) scatter light much more efficiently than coarse particles (between 2.5 and 10 μm diameter). Richards and Saydah (1995) recommend a value of E for coarse particles of 0.4 m^2/g based on studies by White et al. (1994), White and Macias (1990), and Watson et al. (1991).

Given the relationship between concentration and b_{ext} in Eqn. (4-1), the contour plots of b_{ext} (Mm^{-1}) are identical to the $PM_{2.5}$ concentration isopleths (in $\mu g/m^3$) presented in the figures in this section and in Appendices E and G, except the label on each contour is multiplied by a factor of three (i.e., $E_{2.5}$=3.0 m^2/g). Therefore, separate extinction coefficient plots are not presented.

Although the extinction coefficient is a useful measure for characterizing visibility, it does not easily indicate whether a visual change will be perceived. For example, a given change of b_{ext} may not produce a noticeable change in visibility if the baseline b_{ext} is high, but may be quite noticeable under clean baseline conditions. Pitchford and Malm (1994) define a haziness index, expressed in deciview (dv), that is linear with respect to fractional changes in b_{ext}. A change of one deciview corresponds to an approximate 10% change in extinction coefficient, which is considered a small, but perceptible change in visibility. The definition of their index is:

$$\text{haziness (dv)} = 10 \ln(b_{ext}/10.\ Mm^{-1}) \qquad (4\text{-}2)$$

where b_{ext} is expressed in units of Mm^{-1}.

Gridded values of the visibility (in dv) were computed for each simulated day and each emission scenario. The contribution to visibility of regional background and the modeled emissions from the fires were combined to provide estimates of both total visibility and the incremental change in visibility due to the fires. The background visibility was estimated in the following way. Richards and Saydah (1995) summarized background values of b_{ext} at individual stations within the modeling domain. They presented plots of b_{ext} derived from SAMSON visual range data collected at National Weather Service (NWS) sites, PM_{10} concentration measurements available in the U.S. EPA AIRS data base, and $PM_{2.5}$ measurements made during the PREVENT experiments in eastern Washington. However, their data are presented only as point values, and must be gridded to be useful for our purposes. Also, the SAMSON data represents hourly values of b_{ext}, whereas the other data are based on 24-hour average samples of particulate matter concentrations. Richards and Saydah (1995) point out that the AIRS-derived b_{ext} data provides an estimate of regional b_{ext} that may be biased on the high

side, because the AIRS PM_{10} monitors tend to be placed in areas of high particulate concentrations. Because the AIRS monitors reflect, in many cases, the impacts of local sources, the data may overestimate the regional b_{ext}. For this reason, Richards and Saydah (1995) suggest excluding "high values in the PM_{10} data" from the visibility analysis, but do not make specific recommendations.

However, in order to avoid an arbitrarily exclusion of some AIRS data, and to eliminate uncertainties associated with combining b_{ext} of different averaging times (i.e., 1-hour b_{ext} from visual range data and 24-hour b_{ext} derived from the PREVENT dataset), gridded fields of background b_{ext} were based on the SAMSON data base. The life cycle for many of the fires was less than 24-hours, so a short-term average of b_{ext} was most appropriate. Also, the spatial and temporal coverage of the visual range data covered the periods and areas of interest, whereas, the PREVENT data were available for only the summertime wildfire episode, and only for a small subset of the domain (eastern Washington). The visual range data provided a consistent data source covering all of the episodes and all of the simulation days.

The visibility analysis involved the following steps. First, the SAMSON-derived b_{ext} data were gridded using an inverse-distance weighting scheme. This method of gridding the data is a simple, but objective process, that is easy to implement and provides reasonable spatial patterns of b_{ext}. For each day and station, a single hourly value of b_{ext}, derived from the visual range observations made during the time period 0900-1800 hours, was used to characterize the background conditions during the day. The gridded values of background b_{ext} were converted to the deciview scale using Eqn. (4-2).

The model predictions of $PM_{2.5}$ concentrations were used to compute gridded fields of b_{ext} using Eqn. (4-1) with $E_{2.5}$ assumed to be 3.0 m^2/g. Given the much higher extinction efficiency of fine particles, and the fact that nearly all of the particulate matter released from the fires is estimated by EPM to be as fine particles, the effect of coarse particles on visibility was neglected. In order to be consistent with the background visual range data, the peak hourly predicted $PM_{2.5}$ concentration at each grid point during the time period 0900-1800 hours was used in Eqn. (4-1). The modeled b_{ext} values were then converted to gridded deciview values using Eqn. (4-2). Finally, the total (background + fire-induced) visibility (in dv) and the increase of the incremental deciview values (Δdv) due to the fires were computed.

The number of grid cells where Δdv exceeded the perceptible change threshold of 1 dv was computed for each simulation. Tables 4-7 through 4-9 contain the results of the analysis for the prescribed burn emission scenarios on the regional domain. The regional grid contains a total of 3,445 grid cells (65 x 53) with a grid spacing of 20 km. Up to 4.5%, 7.2%, and 32% of the domain was predicted to have a perceptible change in visibility with the highest emission scenario on at least

one of the days, in the early spring, late spring, and fall episodes, respectively. The results of the wildfire simulations are tabulated in Table 4-10. Up to 75% of the grid cells have a perceptible change in visibility during with the highest emission scenario.

A similar analysis was conducted for the fine-scale grid simulations. For this domain, only the base case and base+1500% case emissions for the prescribed fire scenarios, and the 25% and 100% case wildfire emissions for summer episode #1 were evaluated. The fine-scale grid contained 2,500 grid cells (50 x 50) with a grid spacing of 4 km. The number of cells with Δdv of one or more is shown in Table 4-11. It should be noted that the fine-scale simulations include only the effects of local prescribed or wildfire sources within the 200 km x 200 km domain. They do not, for example, include the impacts of other fires that were considered in the regional modeling. A maximum of 7.3% of the grid cells are predicted to have a perceptible change in visibility for the base case emissions scenarios, and up to 39% of the cells are affected for the base+1500% scenarios. In both cases, the fall episode produces the highest impacts. The location of the fine-scale domain was selected to be in an area of expected high future prescribed burn activity. Because this area did not involve significant wildfire activity, there is a relatively small number of cells with a perceptible change in visibility (up to 3.1%).

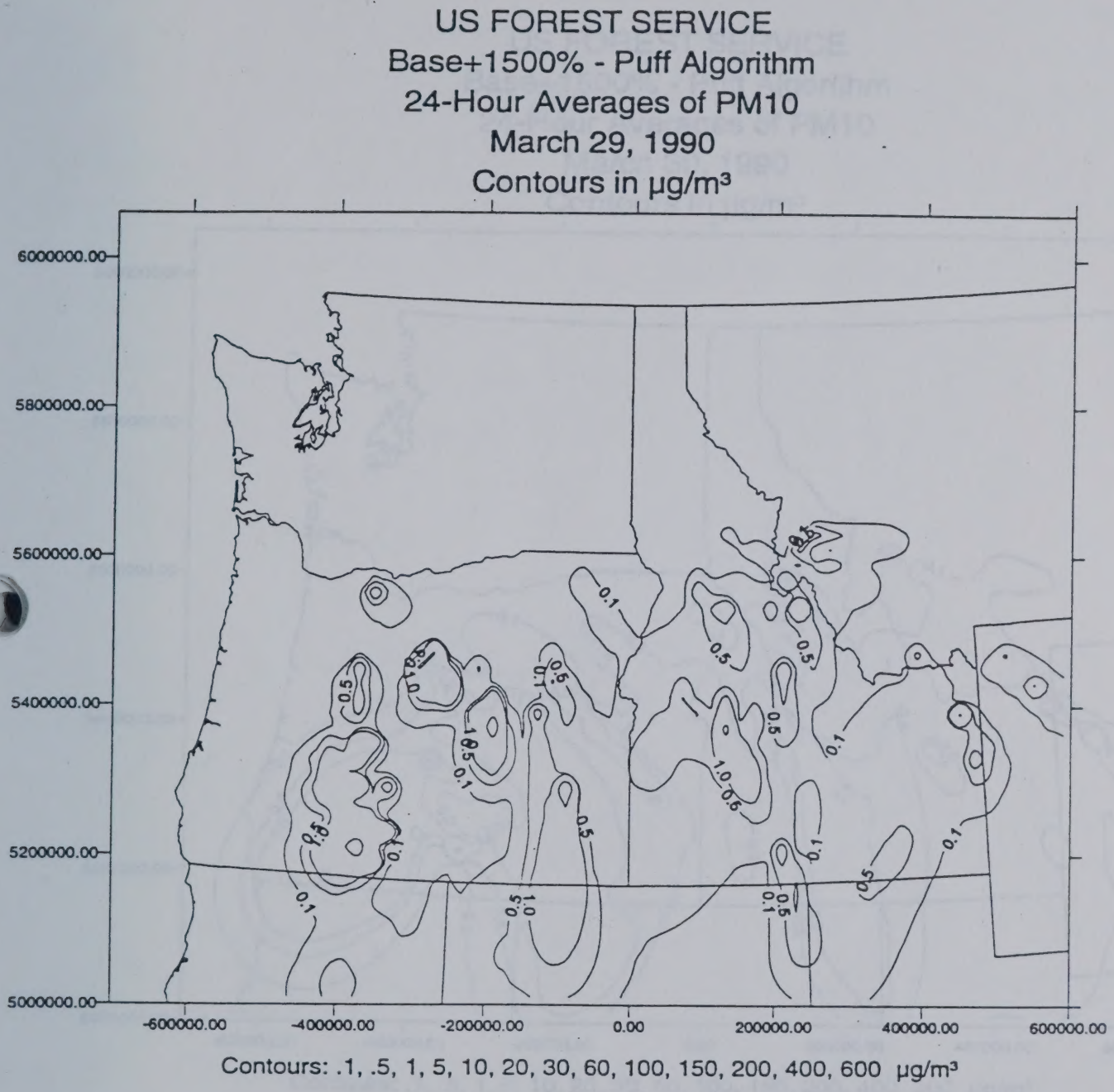


Figure 4-1. Twenty-four hour average concentrations of PM_{10} for the early spring prescribed burn scenario (base + 1500%) for March 29, 1990.

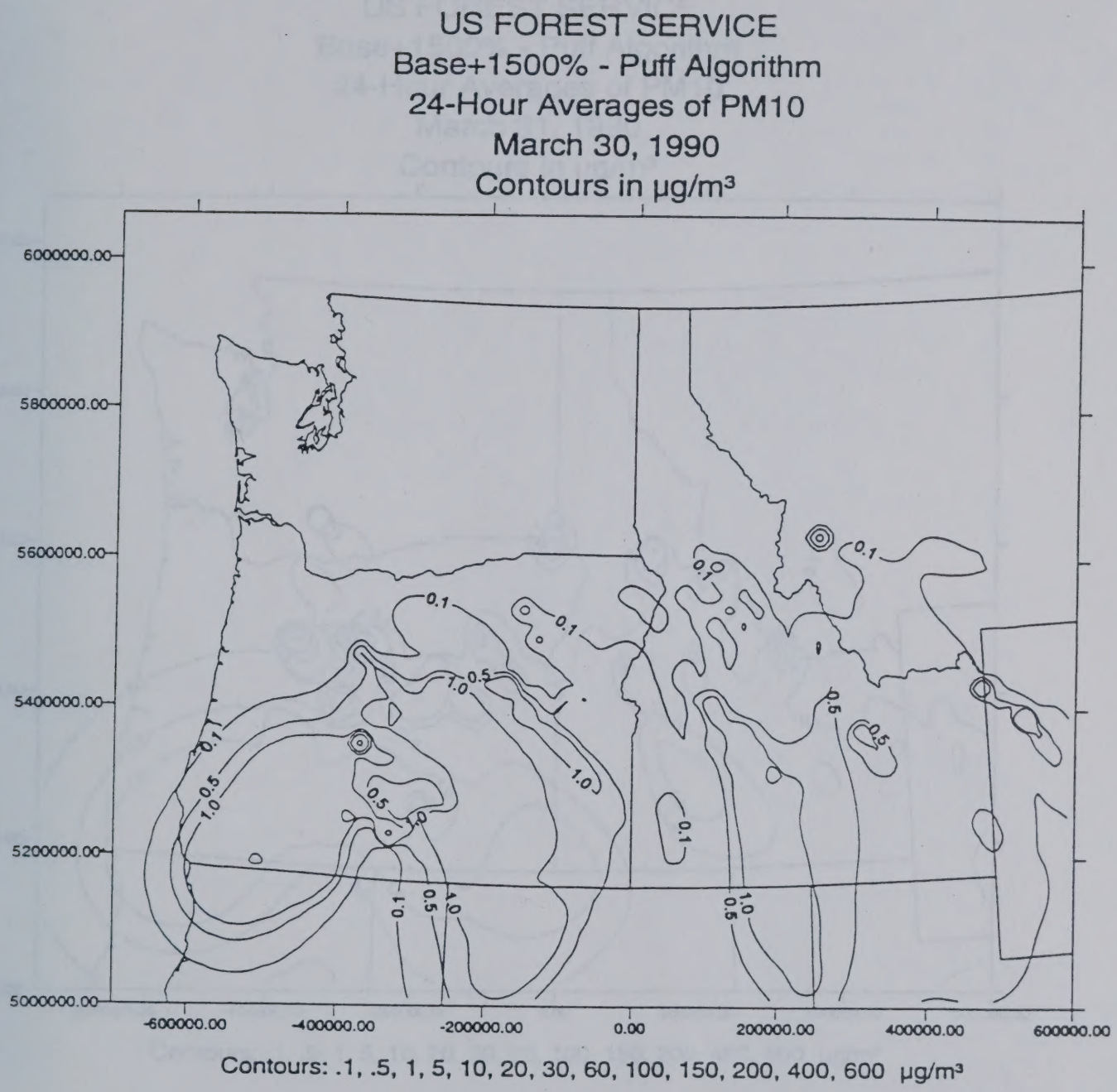


Figure 4-2. Twenty-four hour average concentrations of PM_{10} for the early spring prescribed burn scenario (base + 1500%) for March 30, 1990.

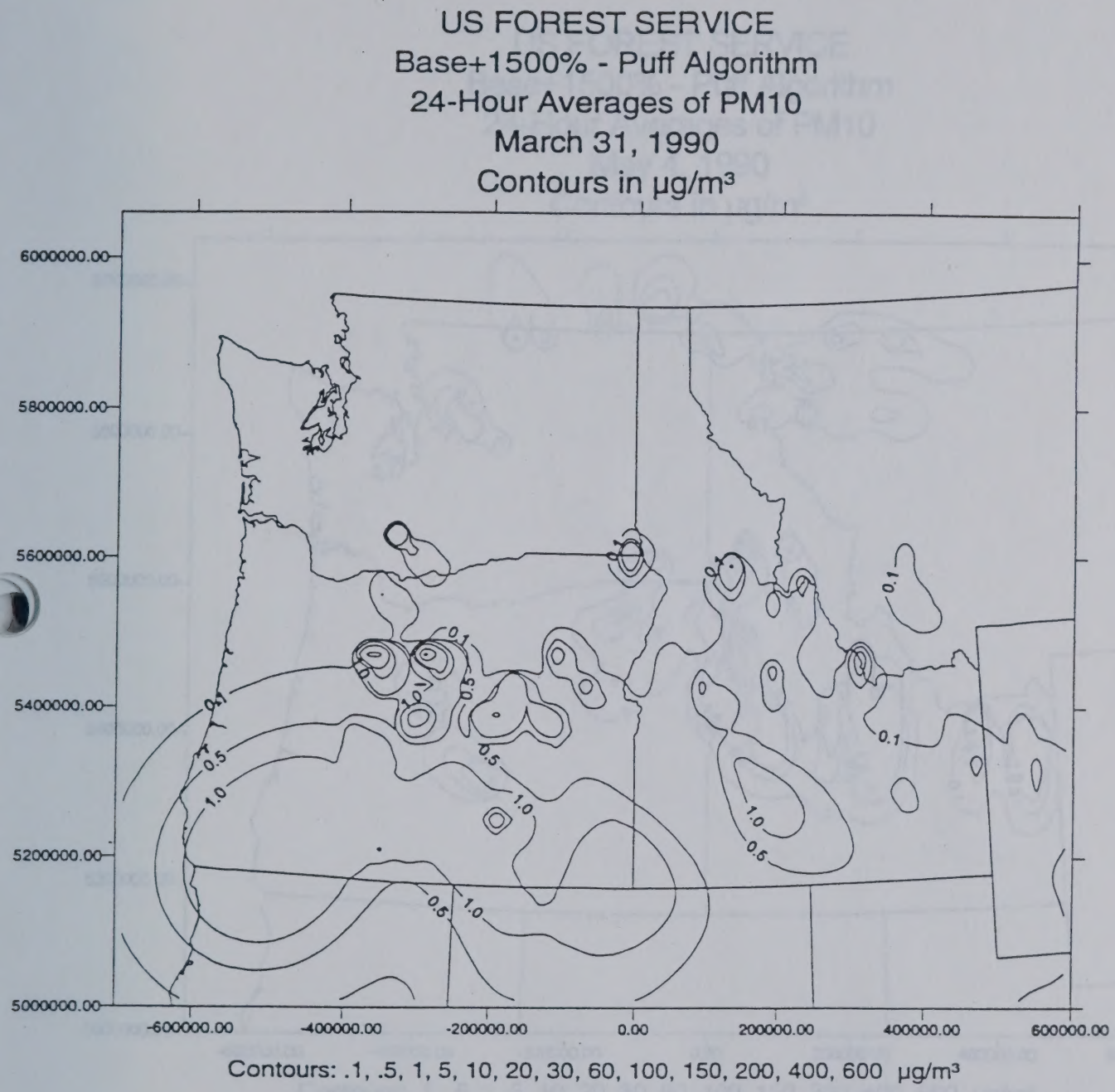


Figure 4-3. Twenty-four hour average concentrations of PM_{10} for the early spring prescribed burn scenario (base + 1500%) for March 31, 1990.

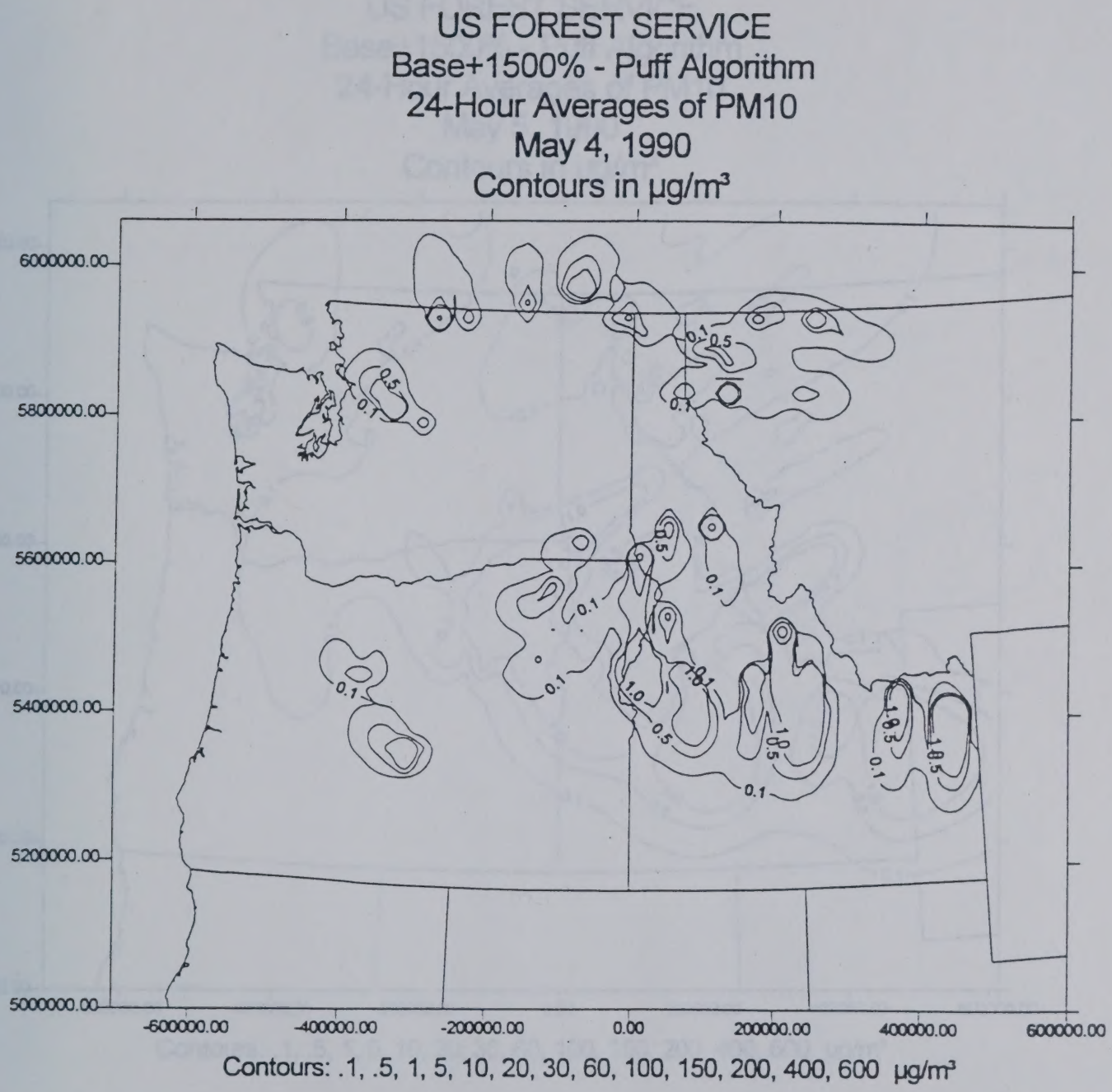


Figure 4-4. Twenty-four hour average concentrations of PM_{10} for the late spring prescribed burn scenario (base + 1500%) for May 4, 1990.

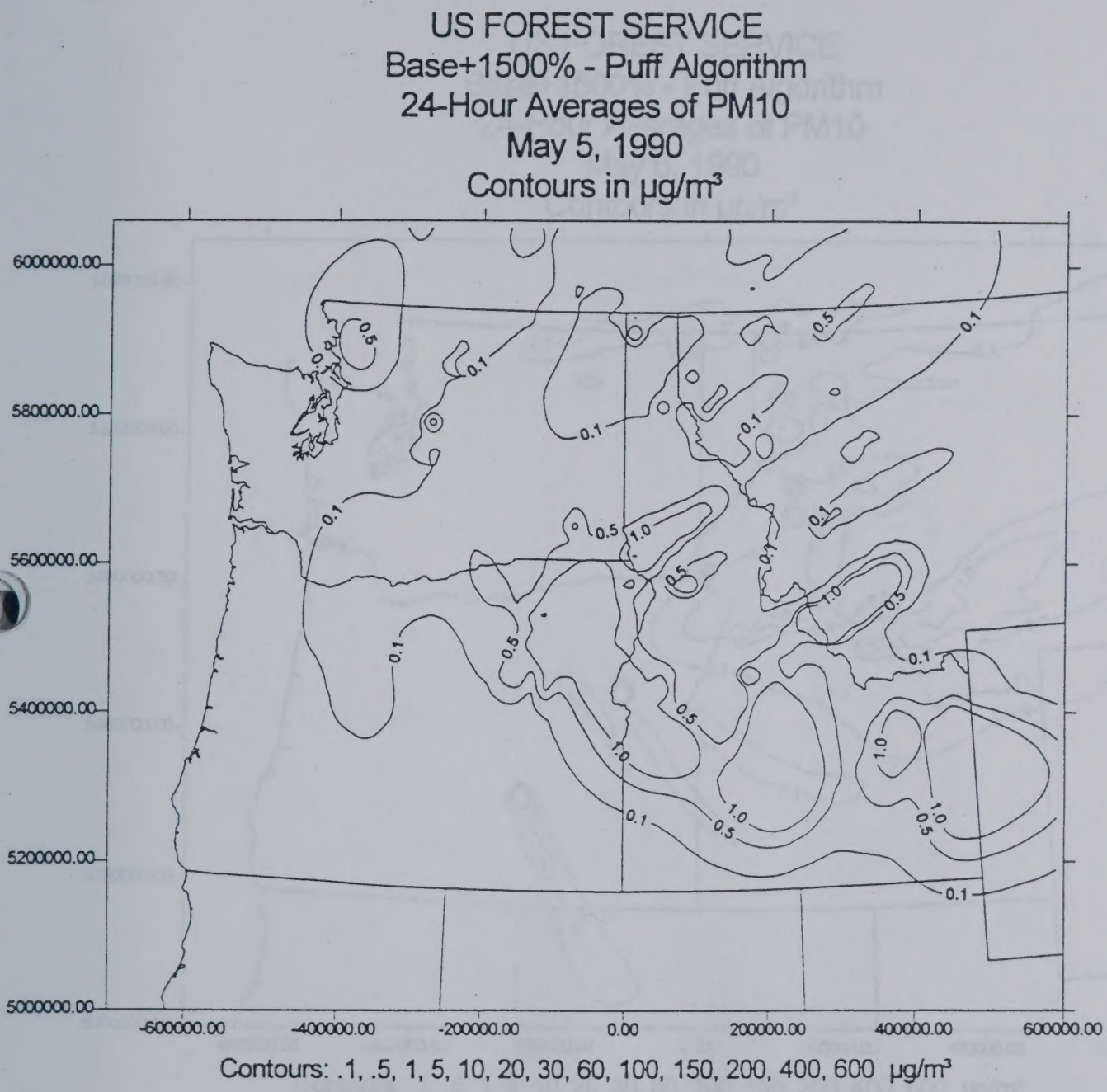


Figure 4-5. Twenty-four hour average concentrations of PM_{10} for the late spring prescribed burn scenario (base + 1500%) for May 5, 1990.

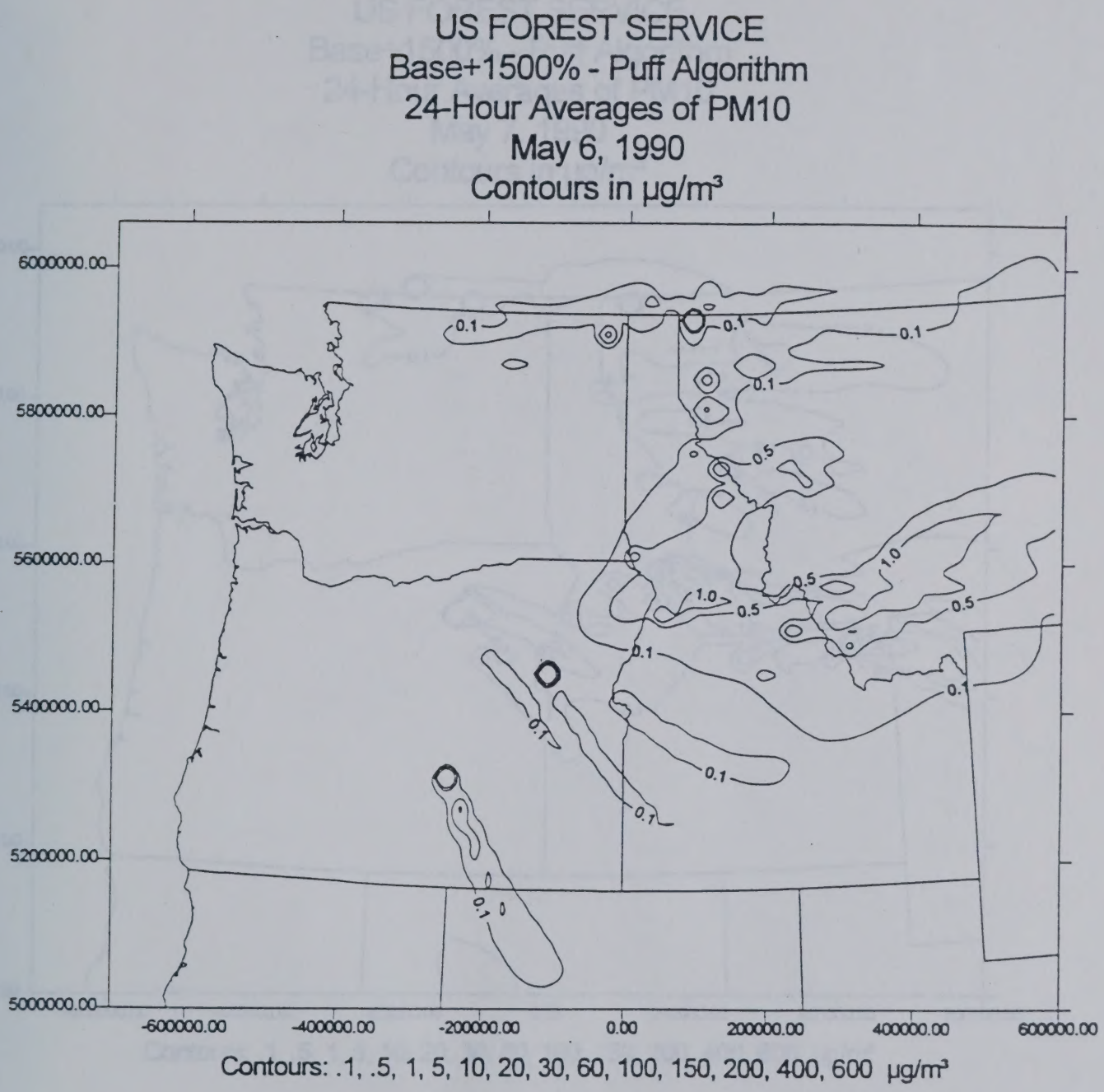


Figure 4-6. Twenty-four hour average concentrations of PM_{10} for the late spring prescribed burn scenario (base + 1500%) for May 6, 1990.

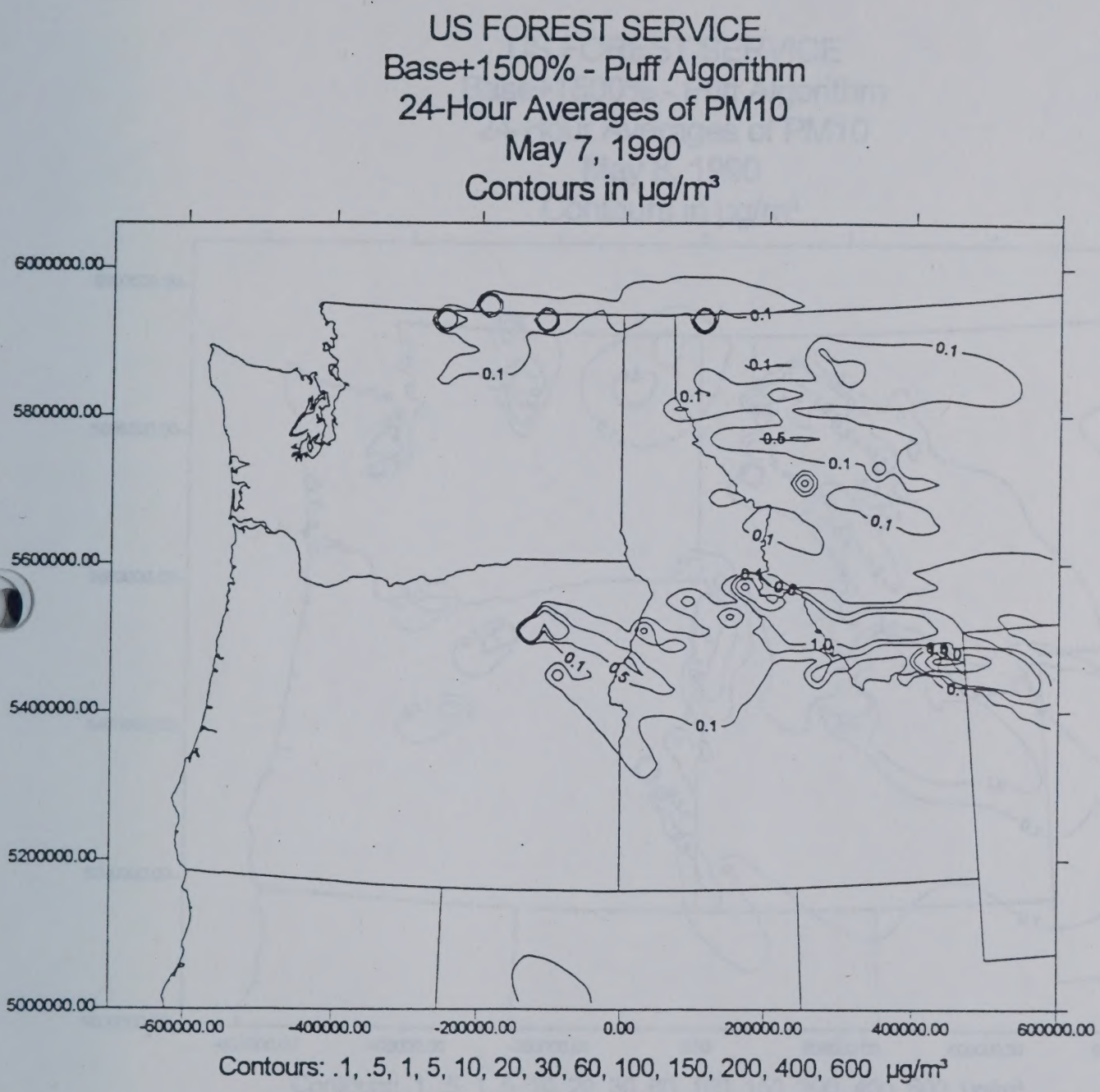


Figure 4-7. Twenty-four hour average concentrations of PM_{10} for the late spring prescribed burn scenario (base + 1500%) for May 7, 1990.

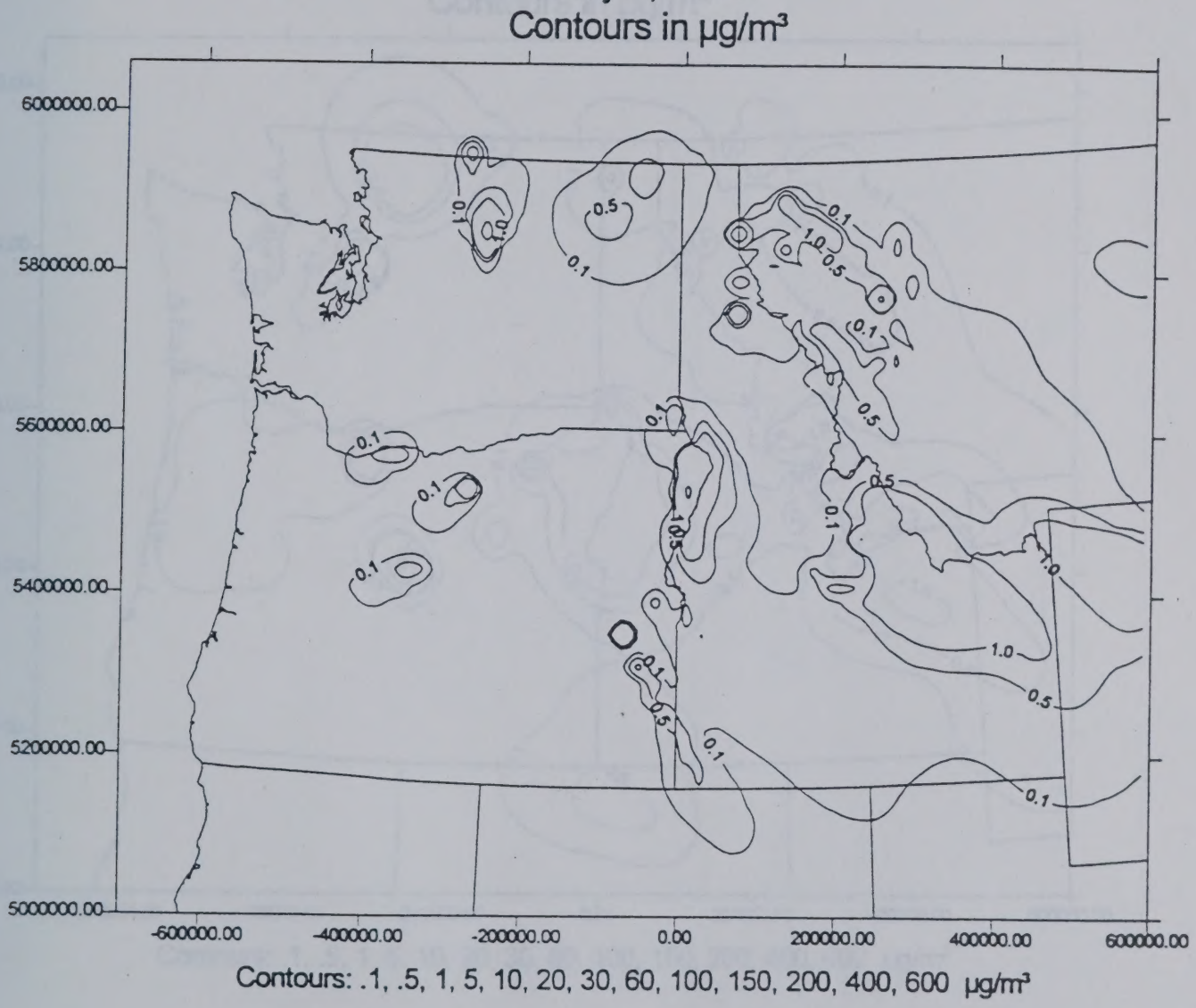


Figure 4-8. Twenty-four hour average concentrations of PM_{10} for the late spring prescribed burn scenario (base + 1500%) for May 8, 1990.

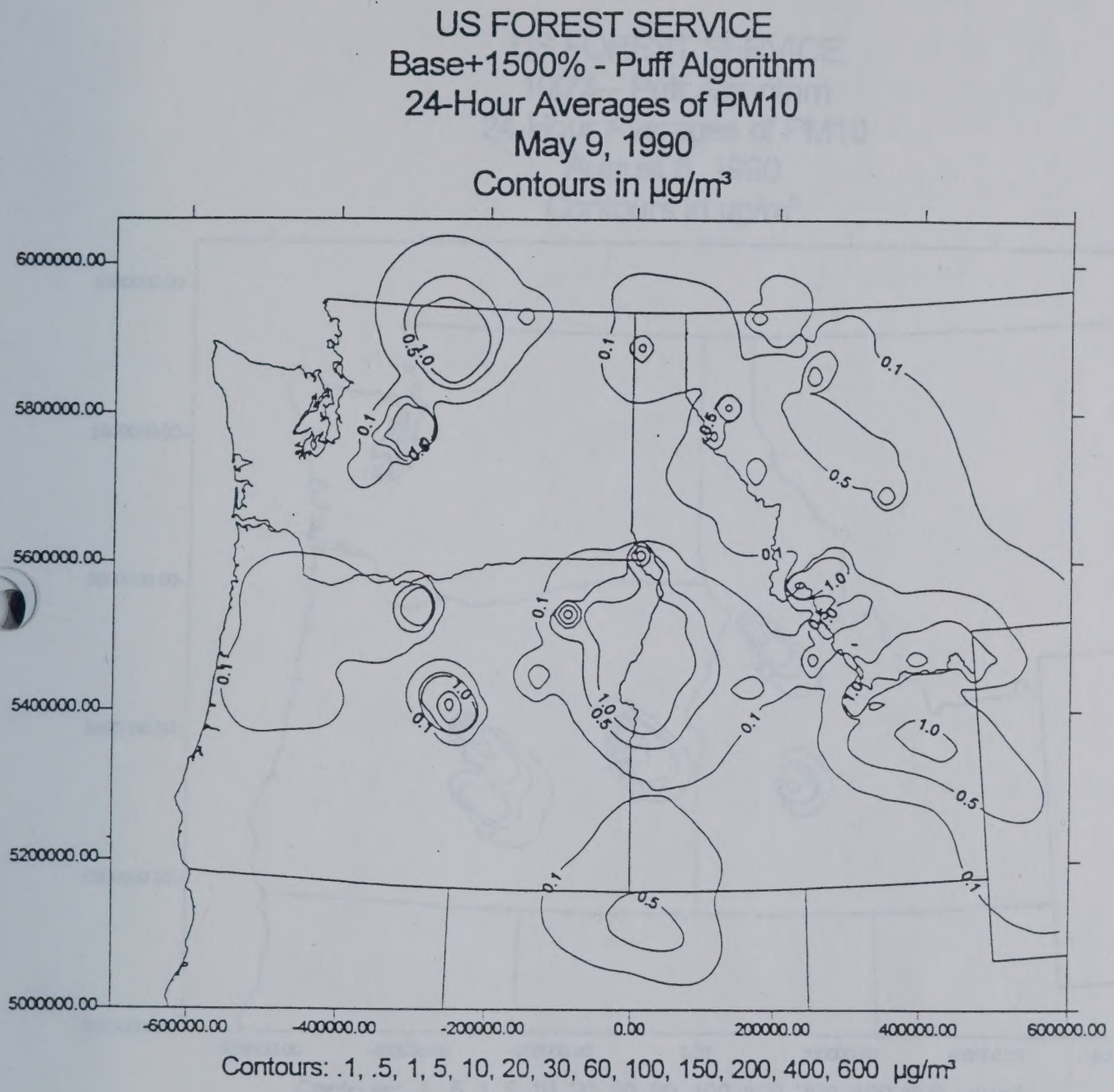


Figure 4-9. Twenty-four hour average concentrations of PM_{10} for the late spring prescribed burn scenario (base + 1500%) for May 9, 1990.

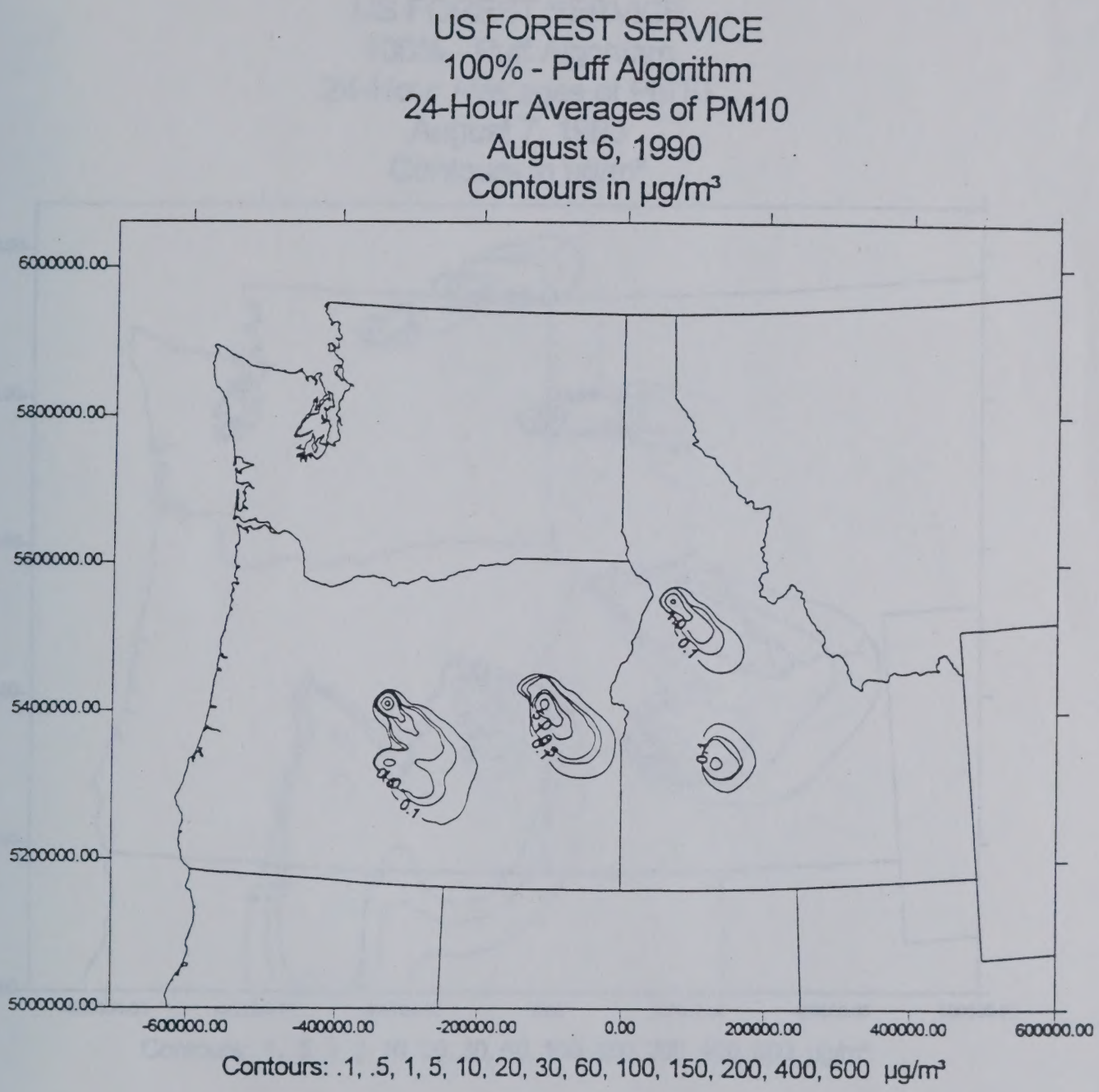


Figure 4-10. Twenty-four hour average concentrations of PM_{10} for the summer wildfire scenario (100% of base case) for August 6, 1990.

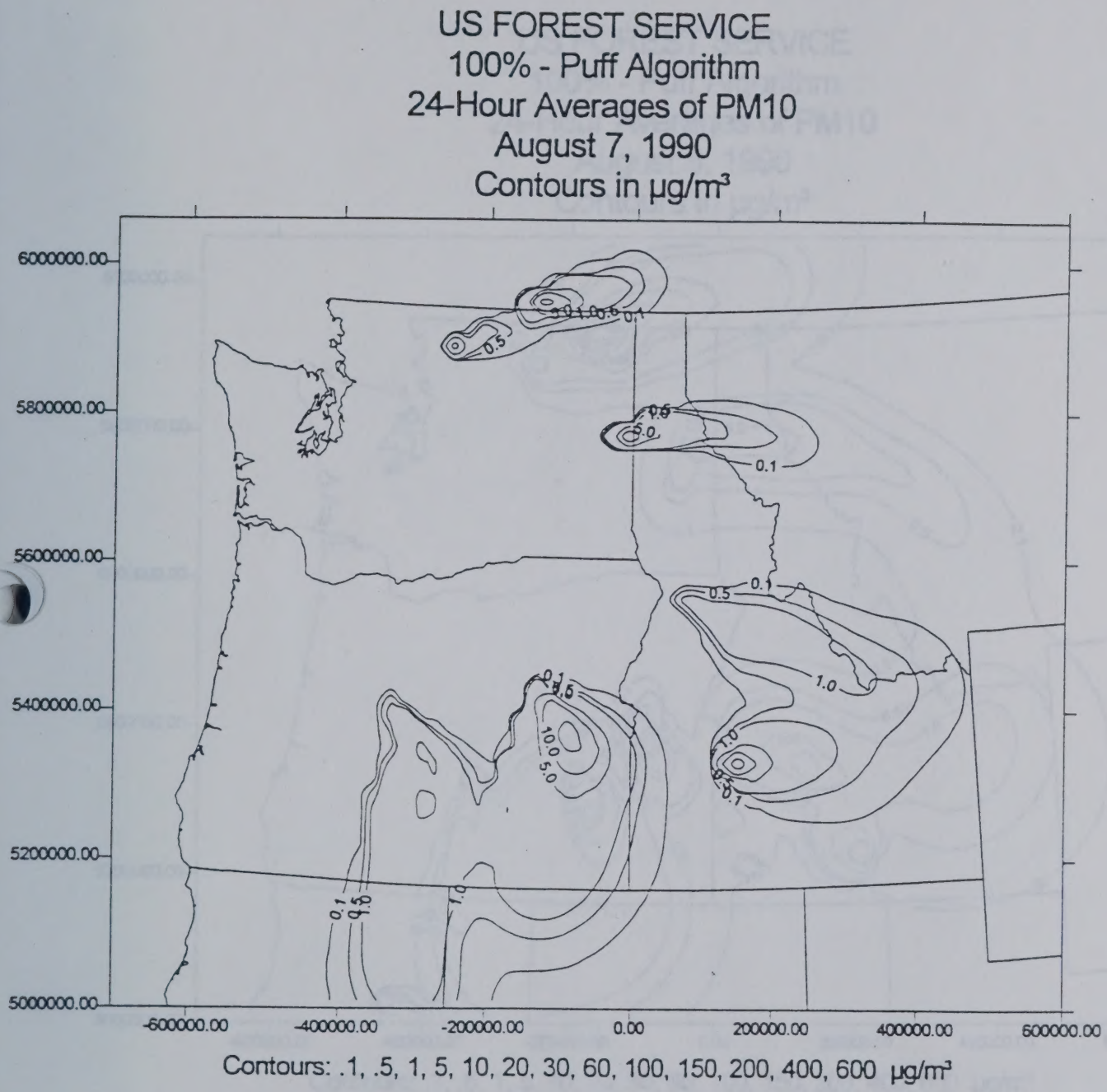


Figure 4-11. Twenty-four hour average concentrations of PM_{10} for the summer wildfire scenario (100% of base case) for August 7, 1990.

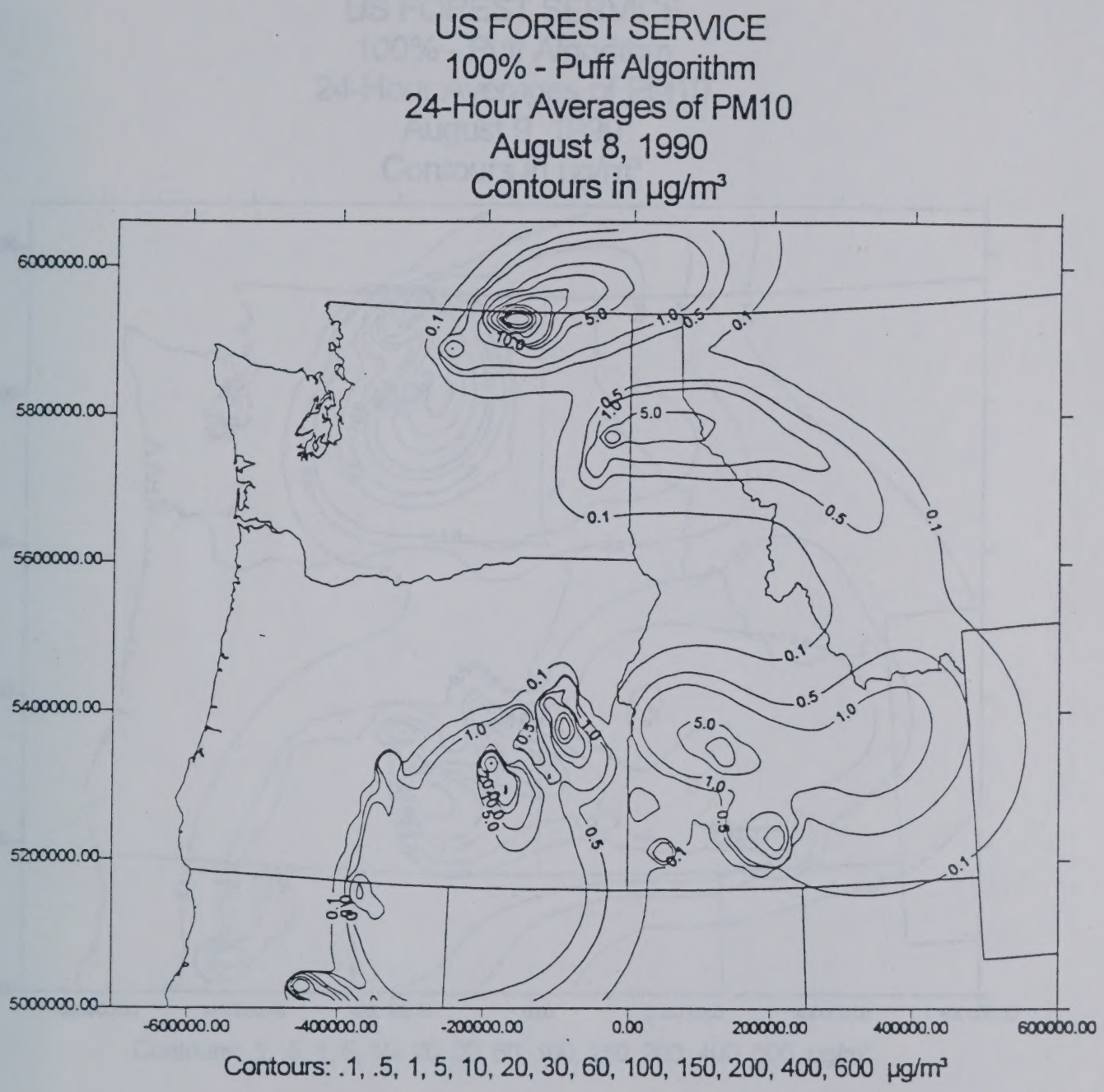


Figure 4-12. Twenty-four hour average concentrations of PM_{10} for the summer wildfire scenario (100% of base case) for August 8, 1990.

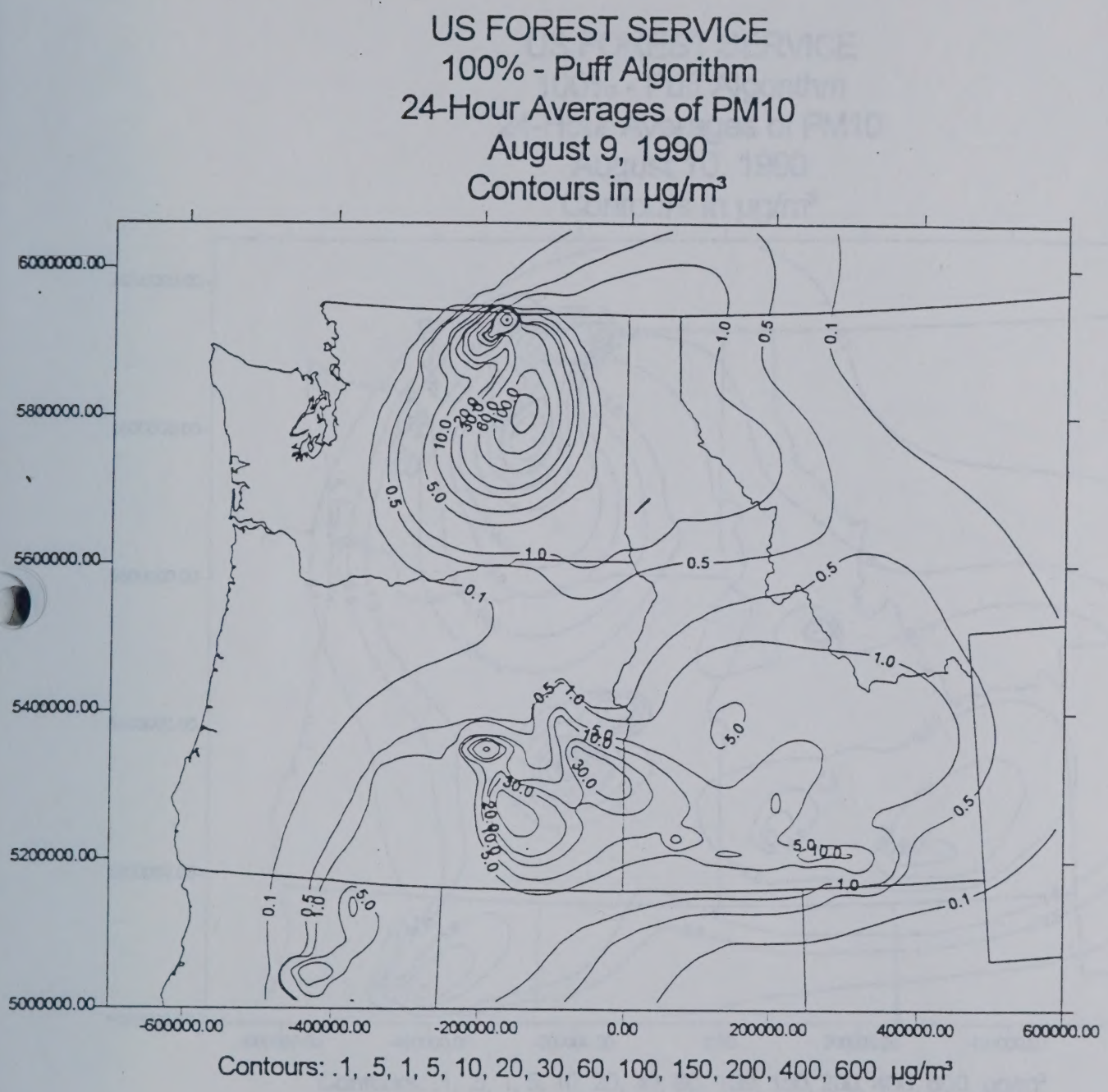


Figure 4-13. Twenty-four hour average concentrations of PM_{10} for the summer wildfire scenario (100% of base case) for August 9, 1990.

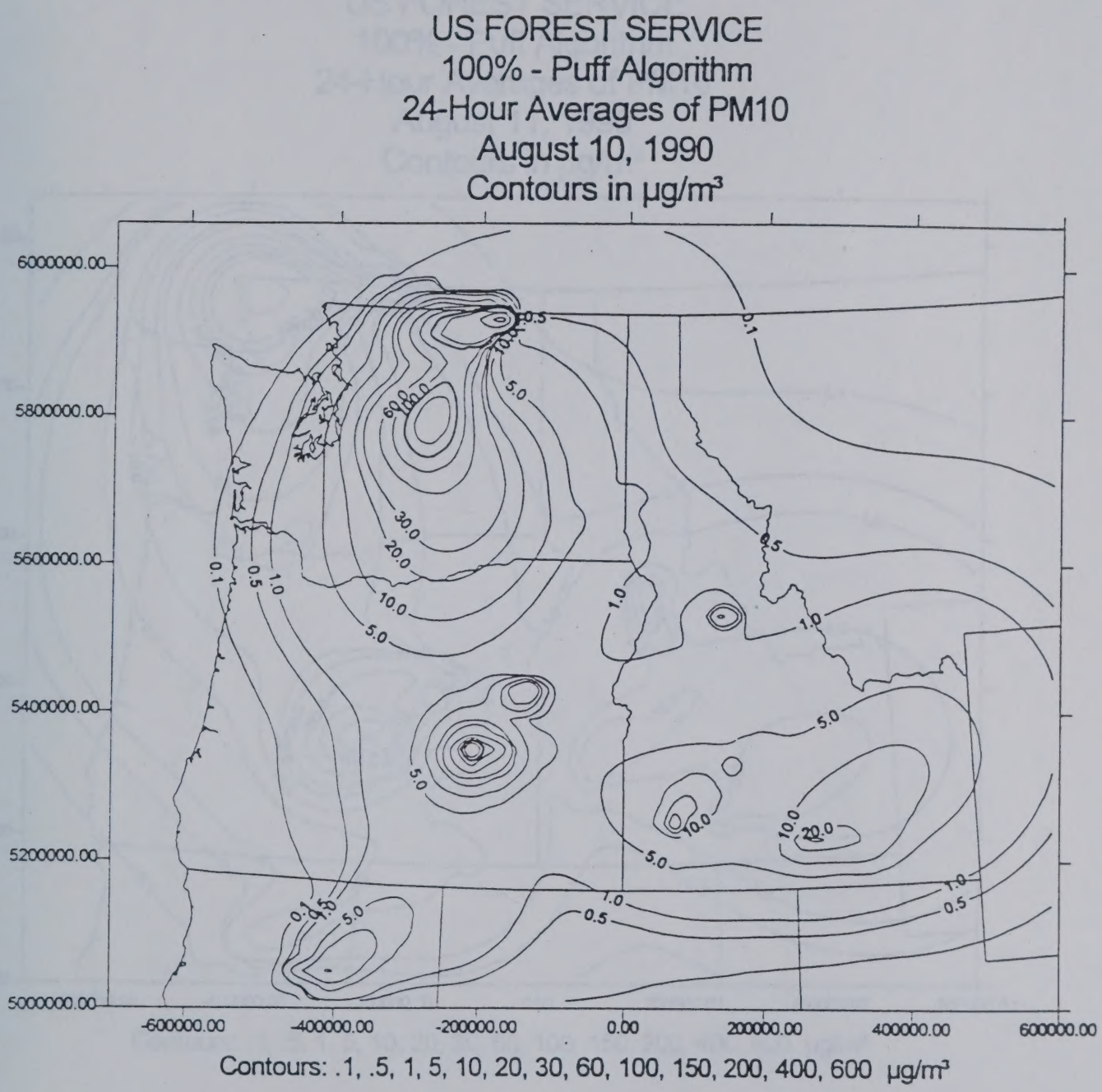


Figure 4-14. Twenty-four hour average concentrations of PM_{10} for the summer wildfire scenario (100% of base case) for August 10, 1990.

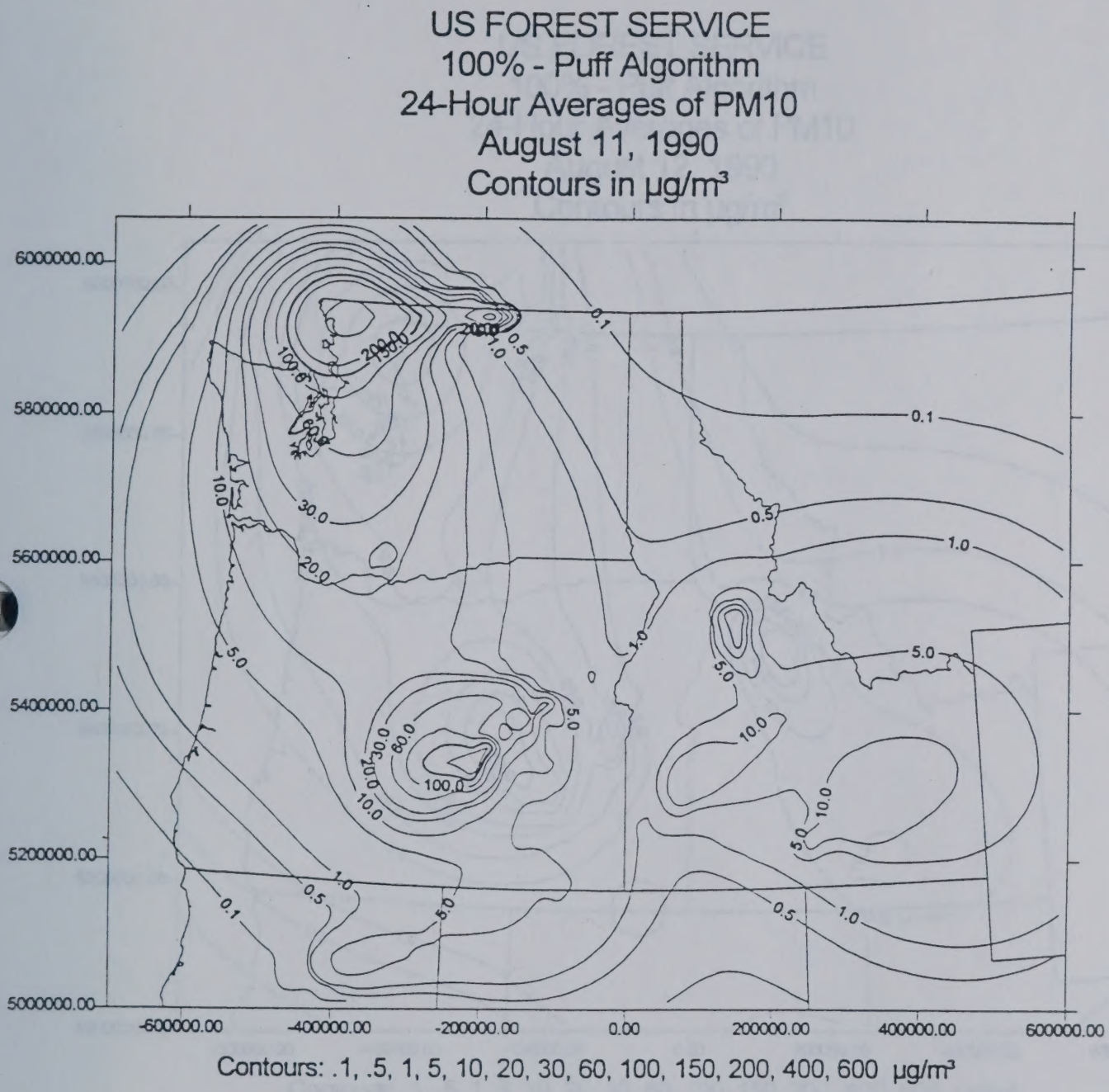


Figure 4-15. Twenty-four hour average concentrations of PM_{10} for the summer wildfire scenario (100% of base case) for August 11, 1990.

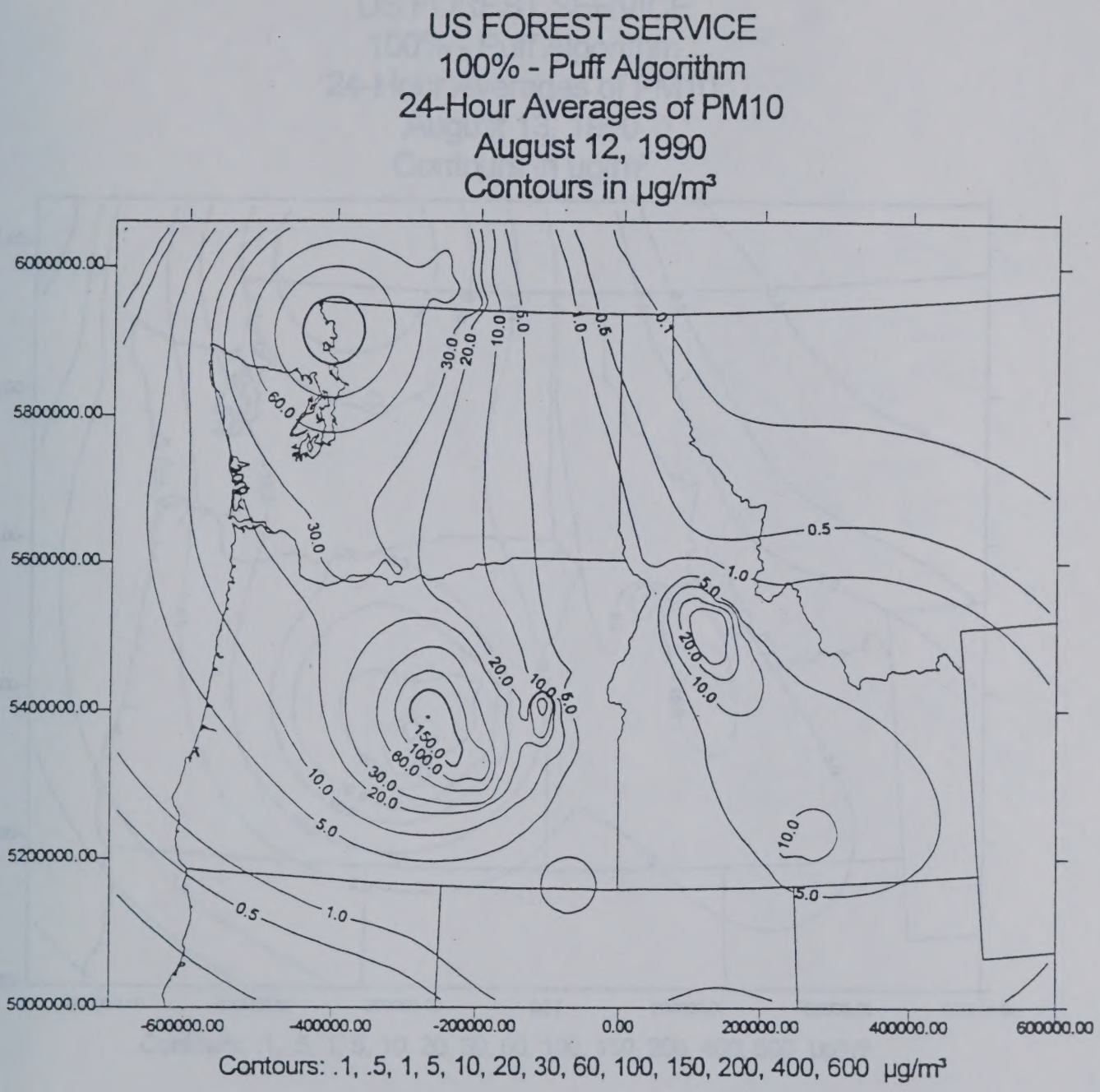


Figure 4-16. Twenty-four hour average concentrations of PM_{10} for the summer wildfire scenario (100% of base case) for August 12, 1990.

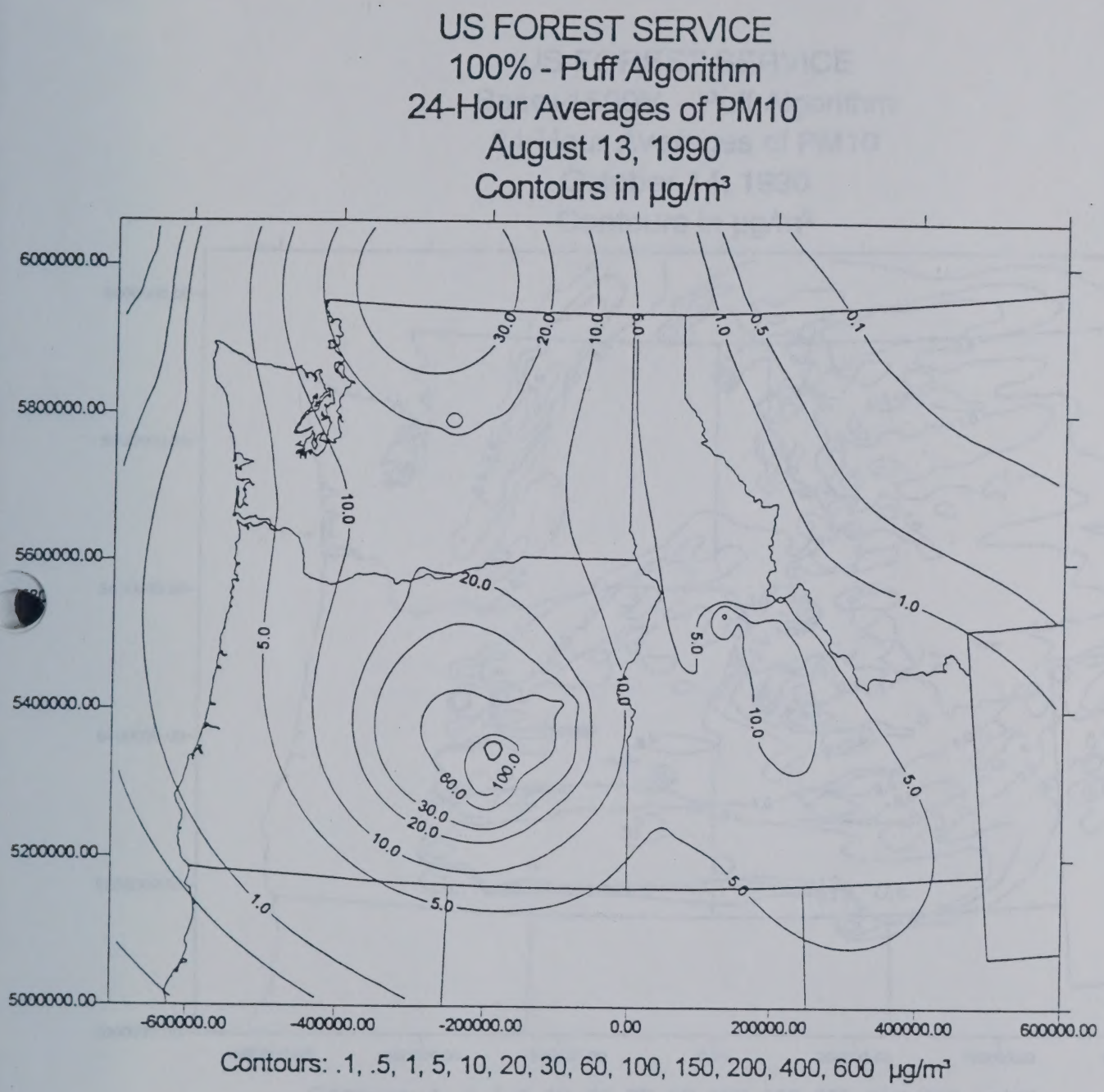


Figure 4-17. Twenty-four hour average concentrations of PM_{10} for the summer wildfire scenario (100% of base case) for August 13, 1990.

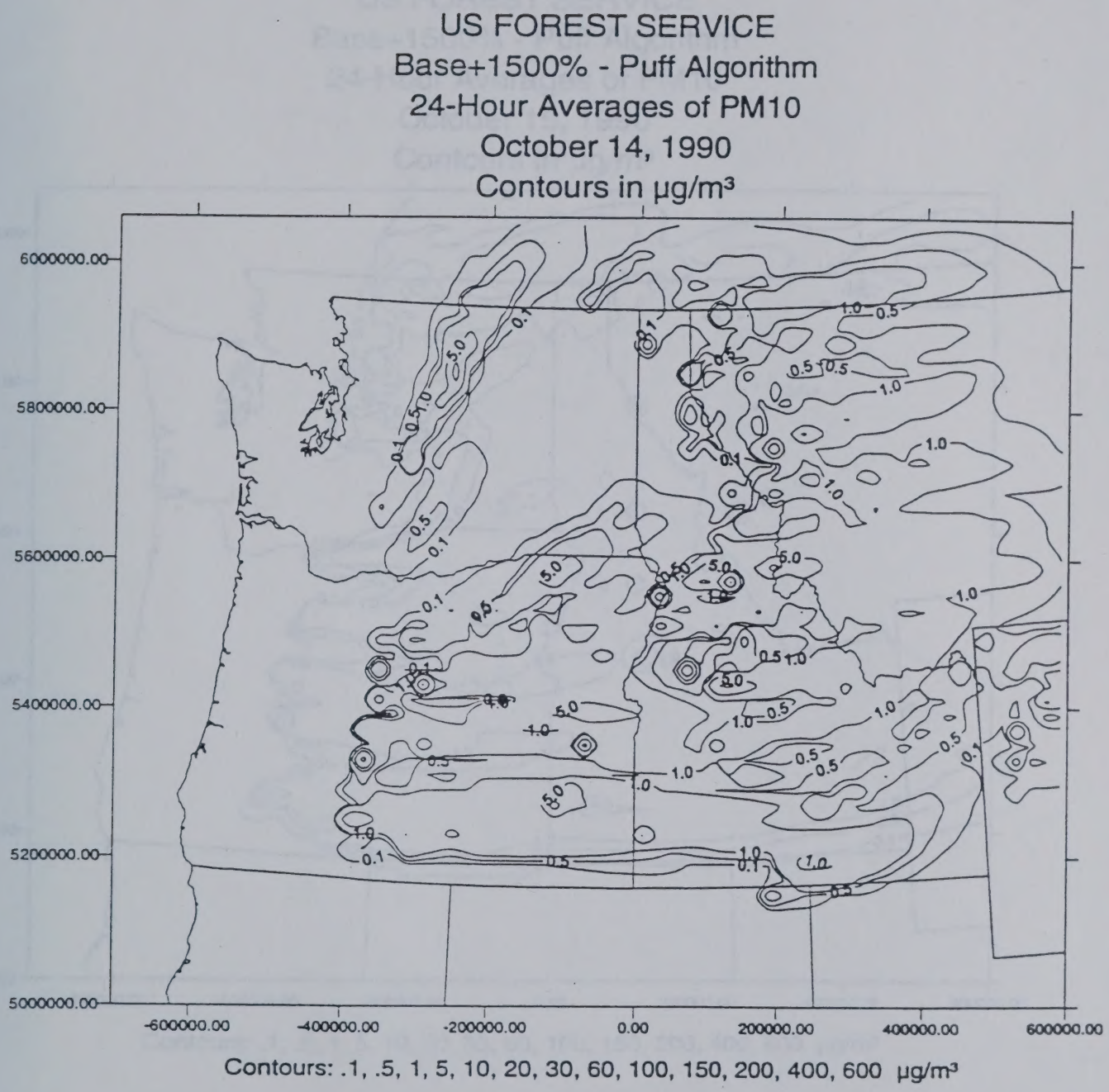


Figure 4-18. Twenty-four hour average concentrations of PM_{10} for the fall prescribed burn scenario (base +1500%) for October 14, 1990.

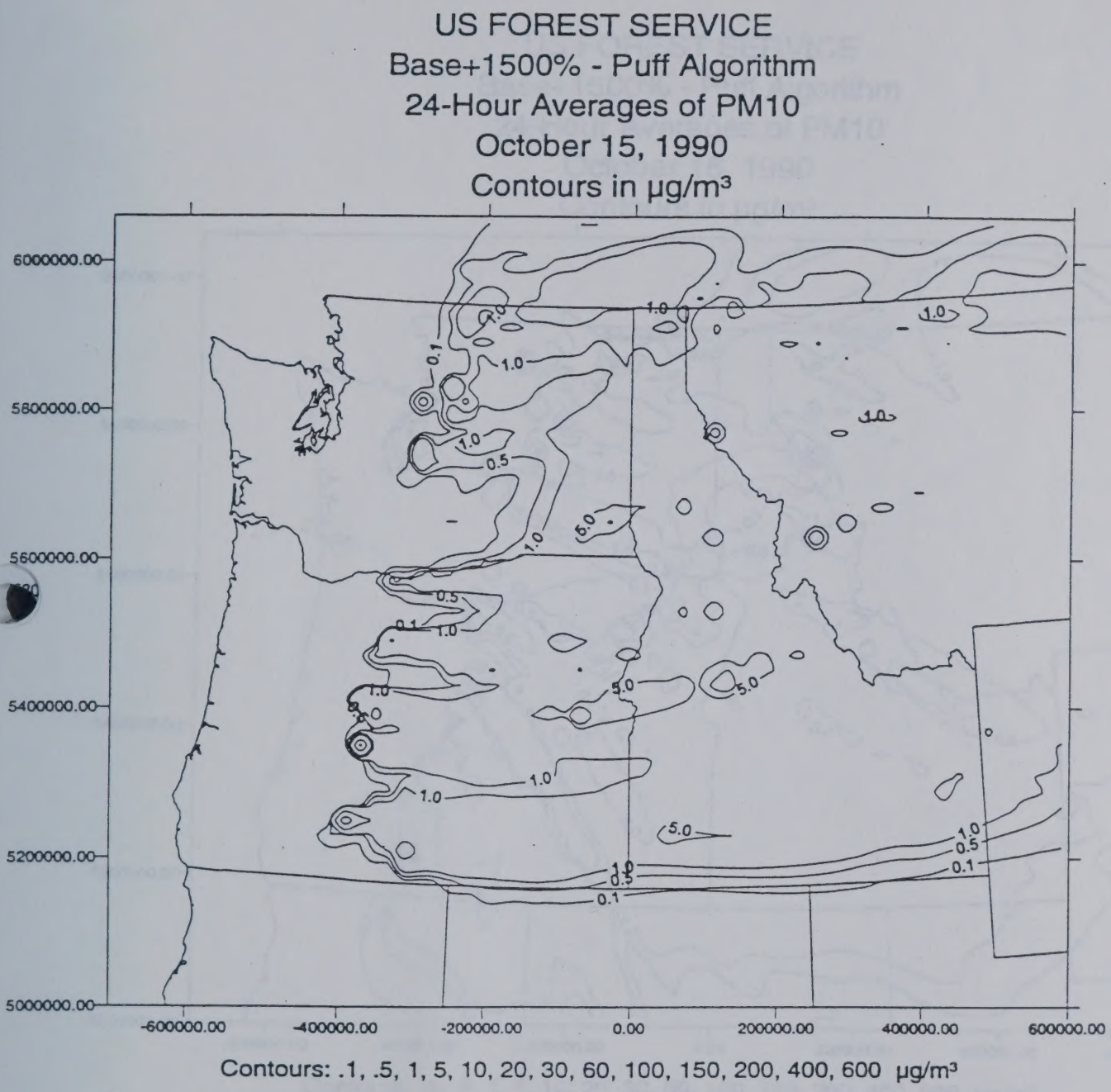


Figure 4-19. Twenty-four hour average concentrations of PM_{10} for the fall prescribed burn scenario (base +1500%) for October 15, 1990.

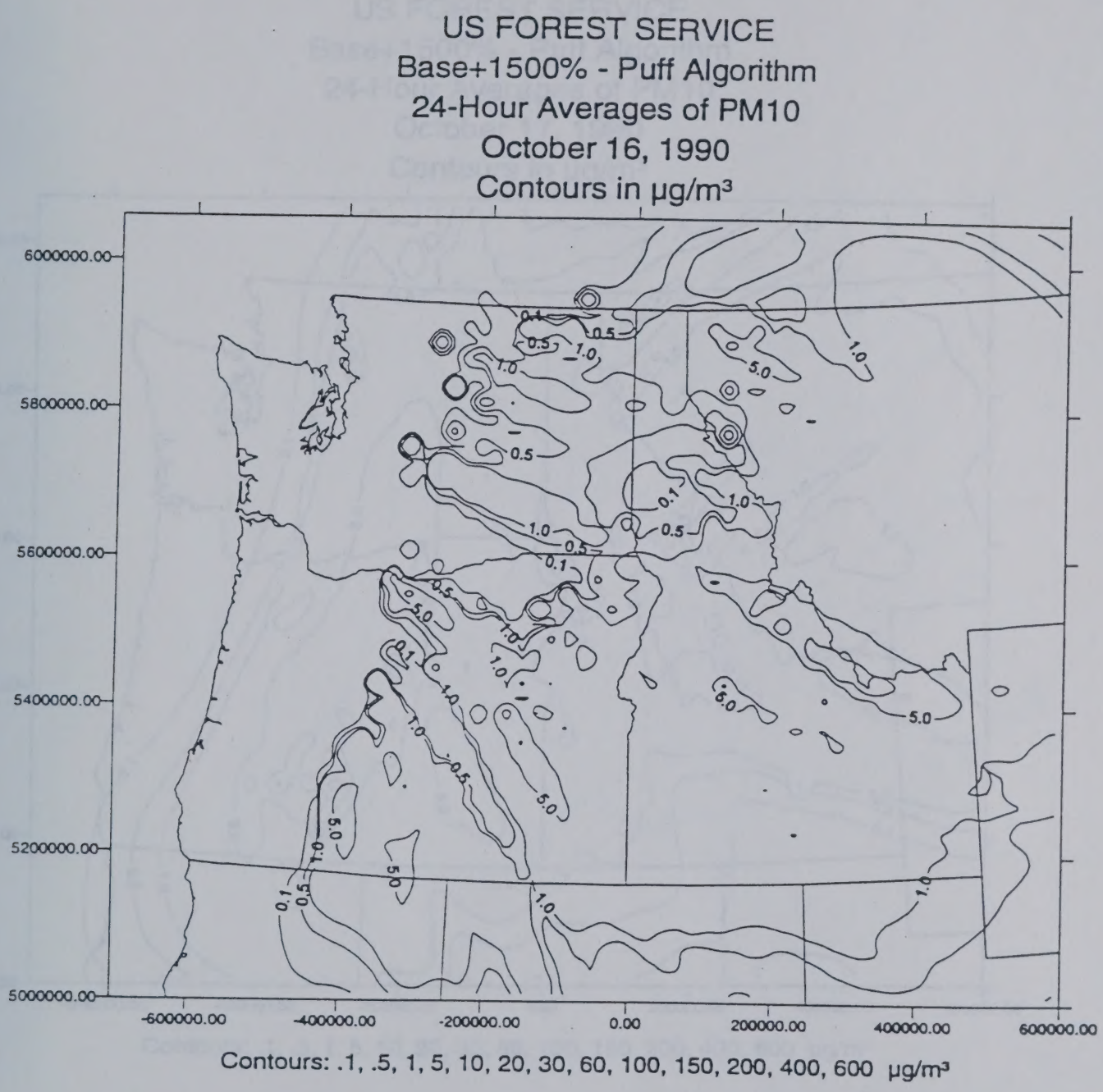


Figure 4-20. Twenty-four hour average concentrations of PM_{10} for the fall prescribed burn scenario (base +1500%) for October 16, 1990.

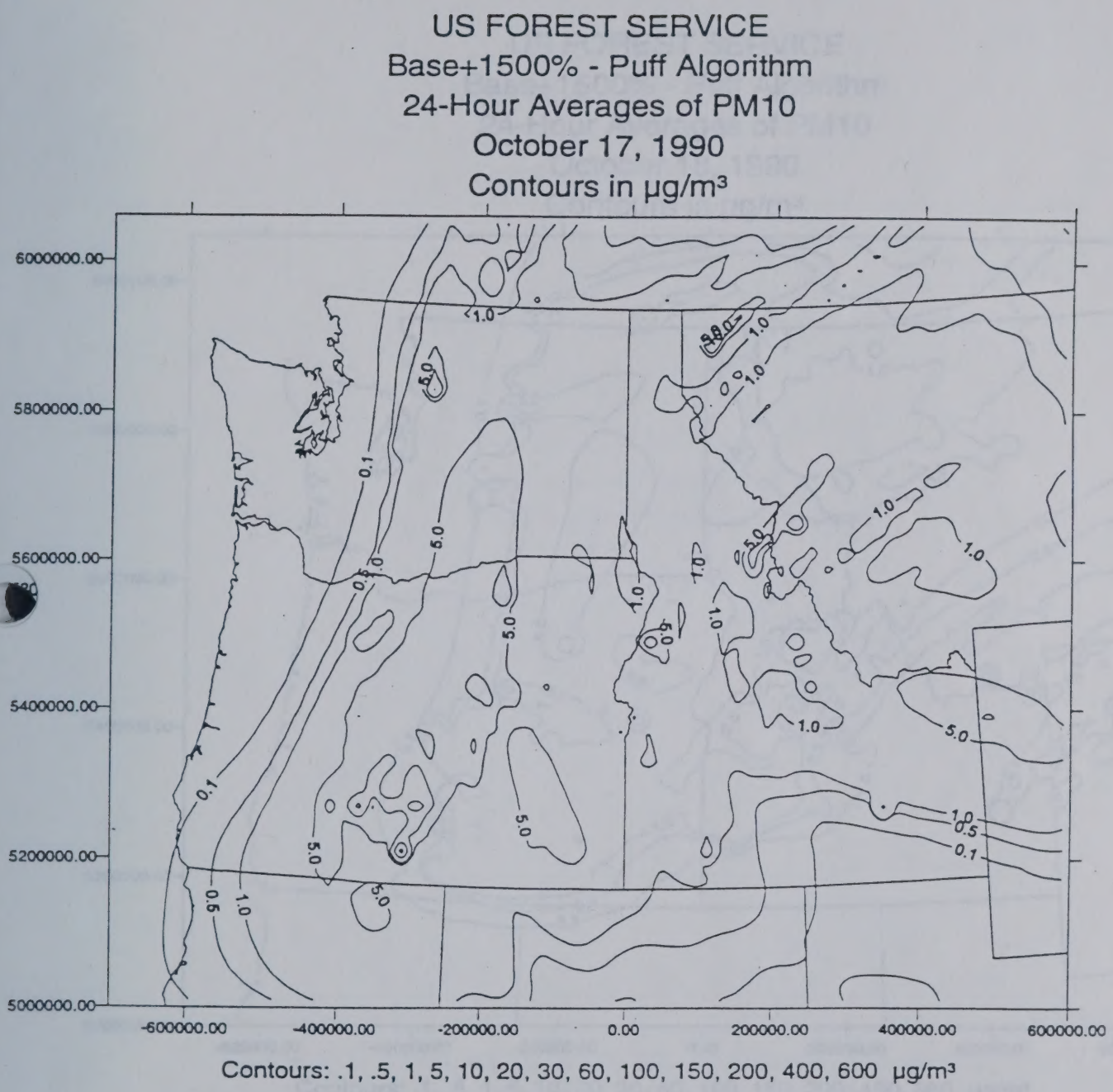


Figure 4-21. Twenty-four hour average concentrations of PM_{10} for the fall prescribed burn scenario (base +1500%) for October 17, 1990.

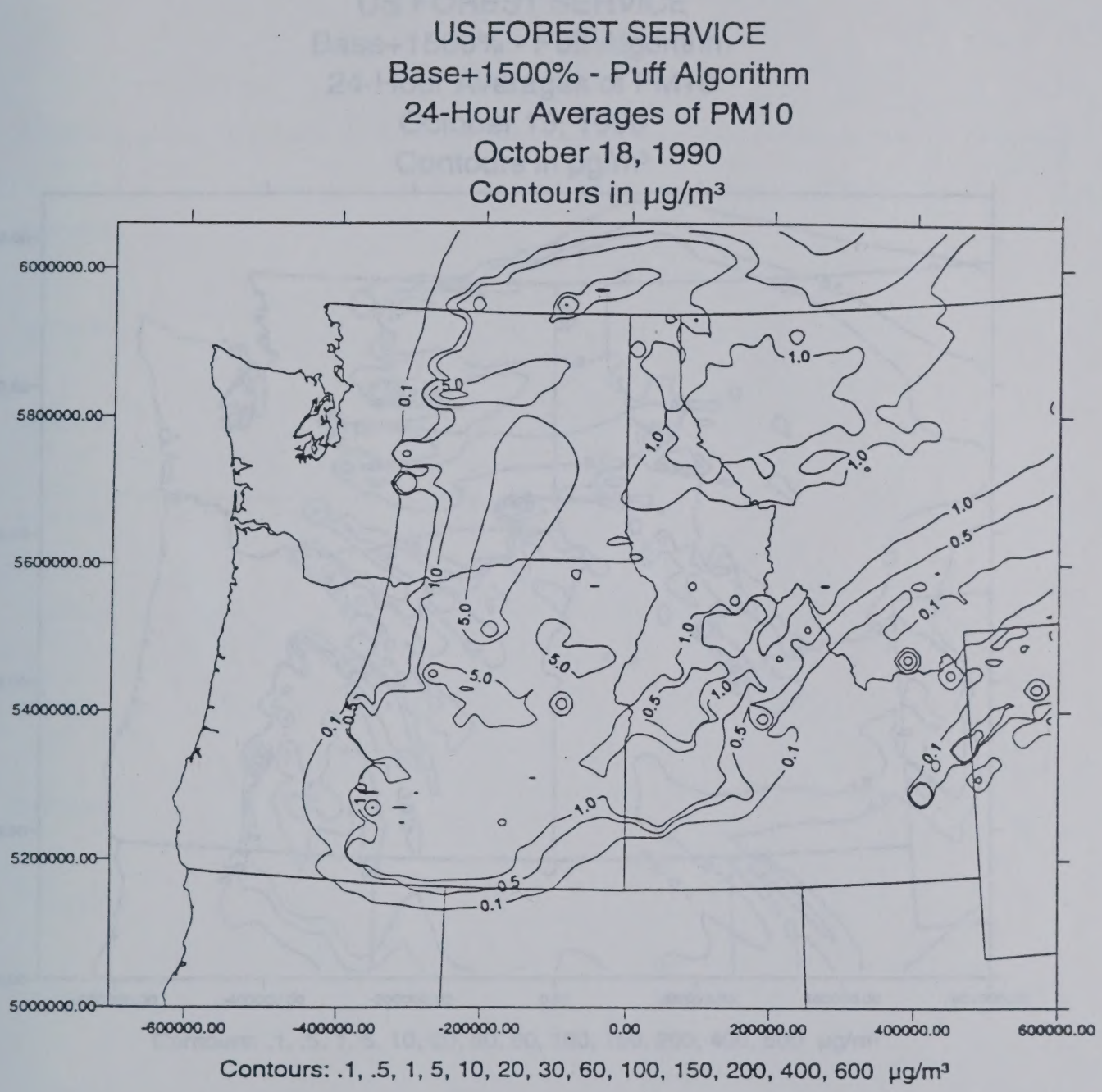


Figure 4-22. Twenty-four hour average concentrations of PM_{10} for the fall prescribed burn scenario (base +1500%) for October 18, 1990.

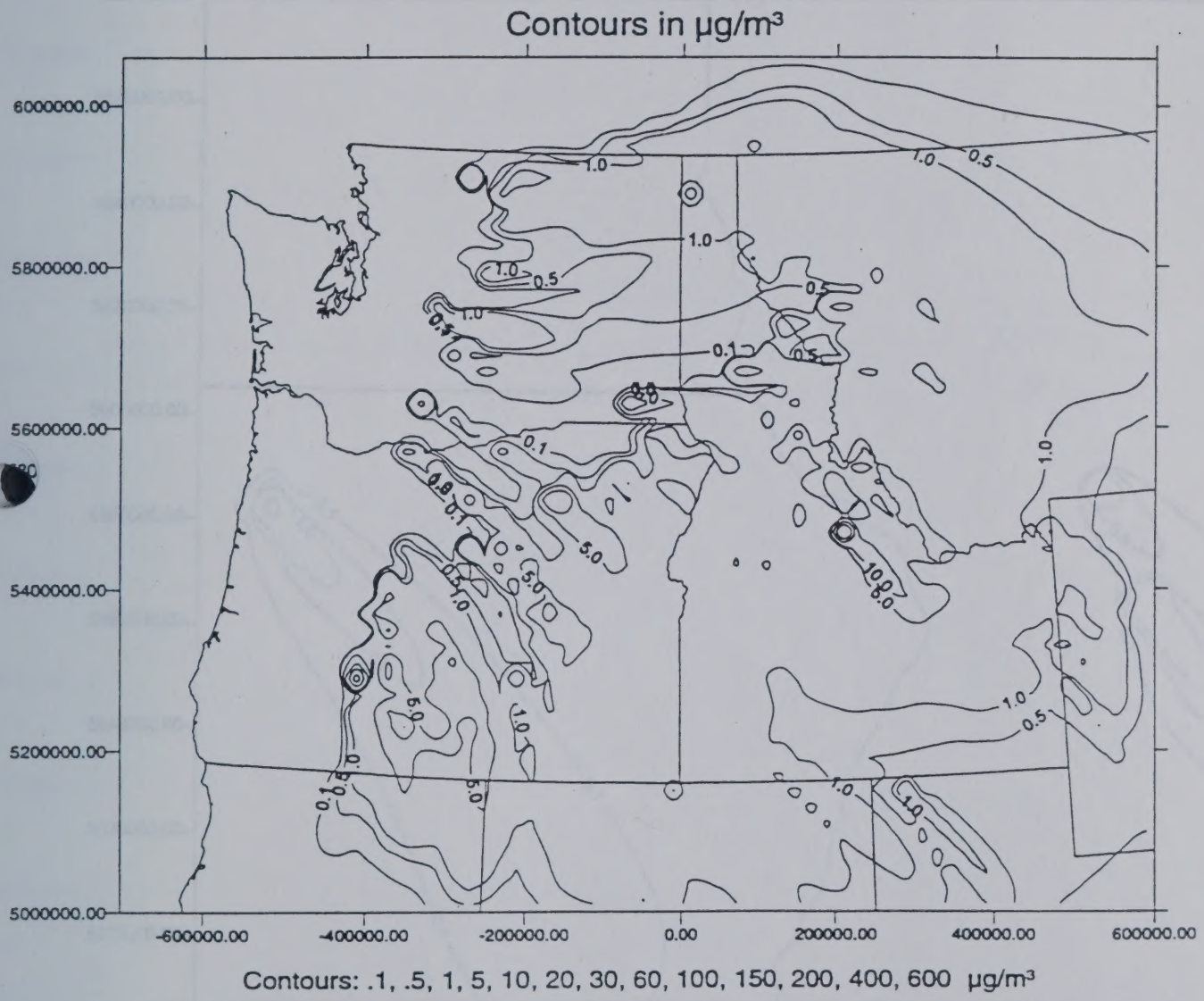
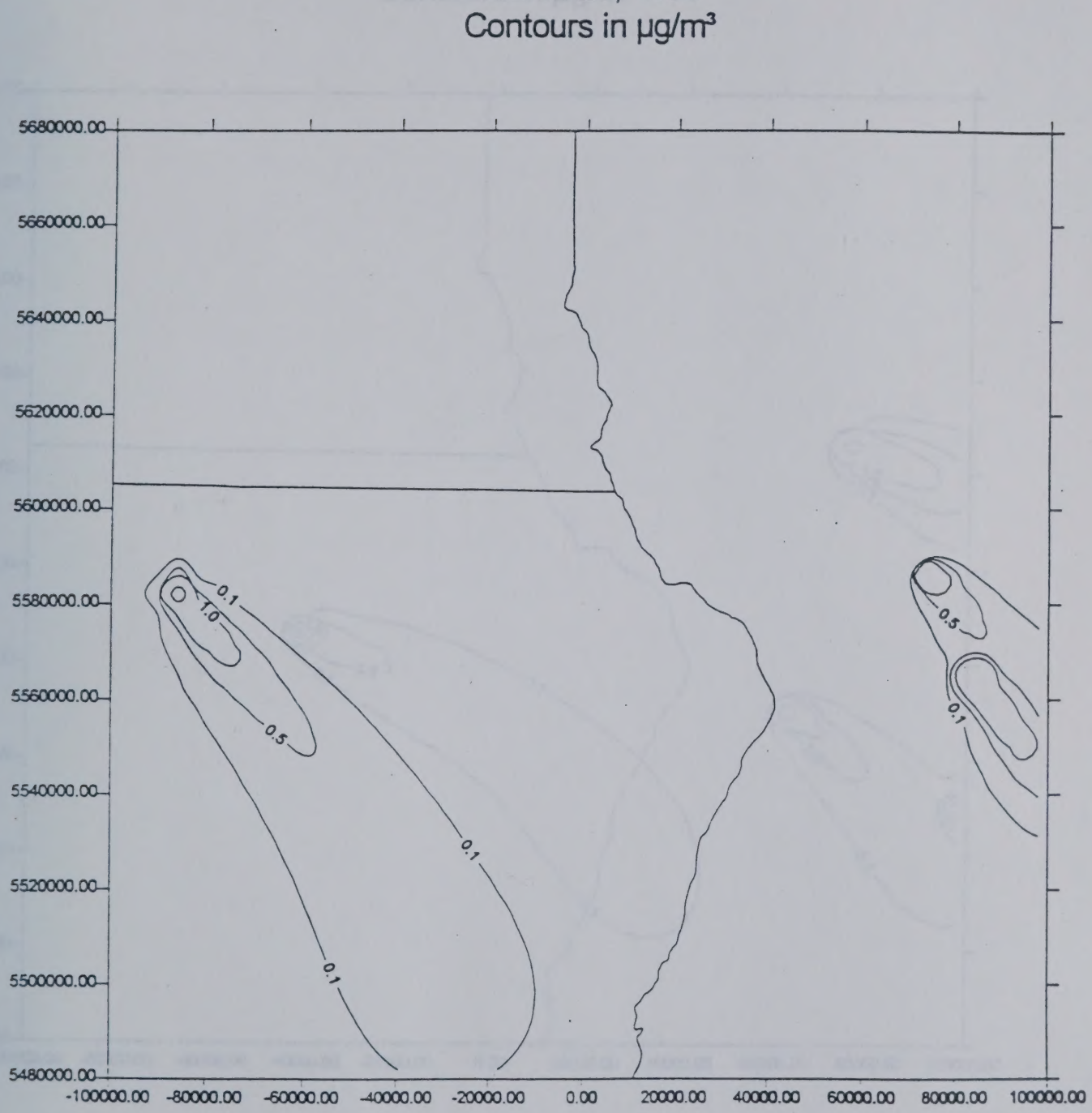


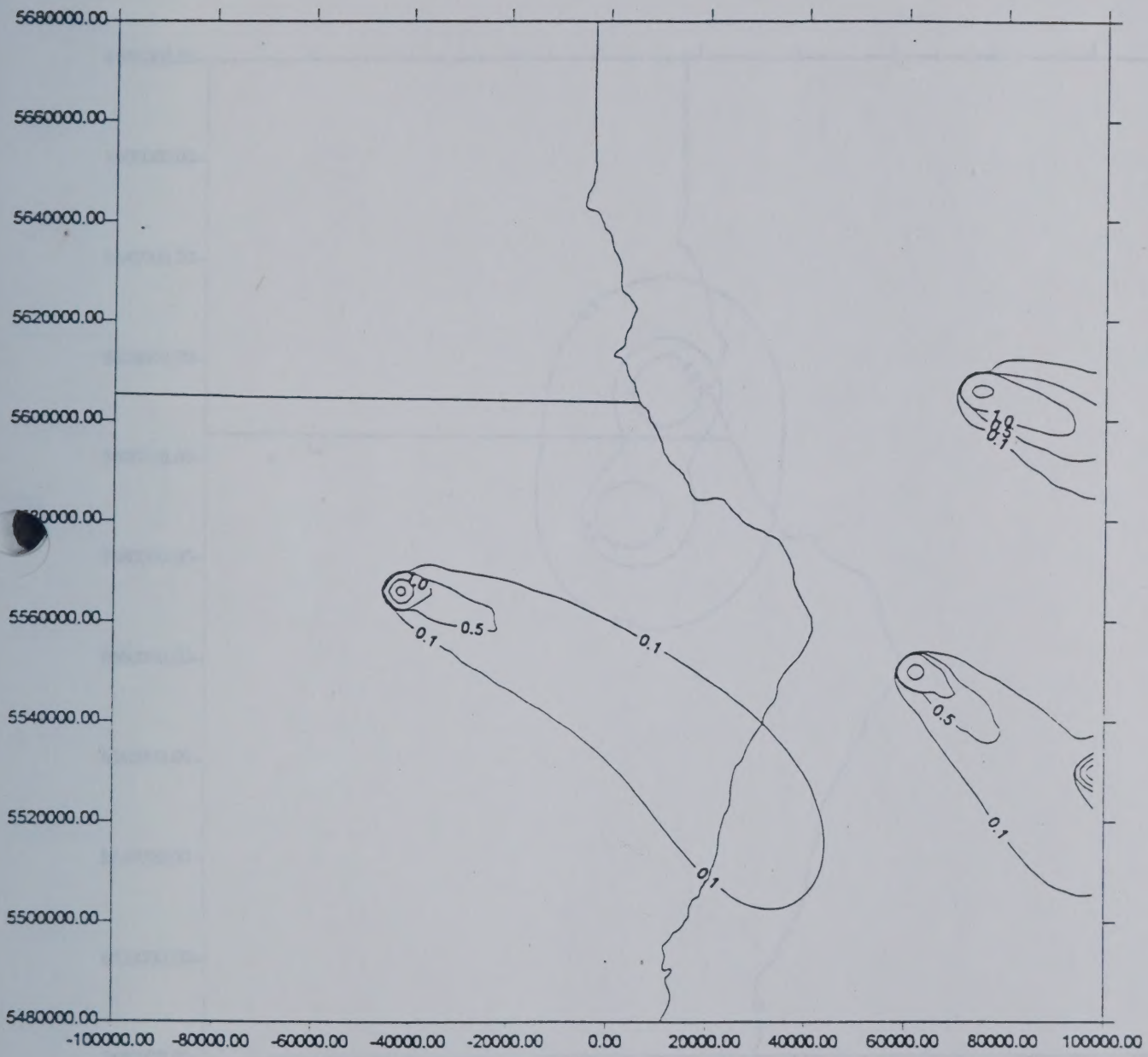
Figure 4-23. Twenty-four hour average concentrations of PM_{10} for the fall prescribed burn scenario (base +1500%) for October 19, 1990.



Contours: .1, .5, 1, 5, 10, 15, 20, 30, 60, 100, 150, 200, 400, 600 µg/m³

Figure 4-24. Twenty-four hour average fine-scale concentrations of PM_{10} for the early spring prescribed burn scenario (base + 1500%) for March 29, 1990.

US FOREST SERVICE
Base+1500% - Slug Algorithm
24-Hour Averages of PM10
March 30, 1990
Contours in μg/m³



Contours: .1, .5, 1, 5, 10, 15, 20, 30, 60, 100, 150, 200, 400, 600 μg/m³

Figure 4-25. Twenty-four hour average fine-scale concentrations of PM_{10} for the early spring prescribed burn scenario (base + 1500%) for March 30, 1990.

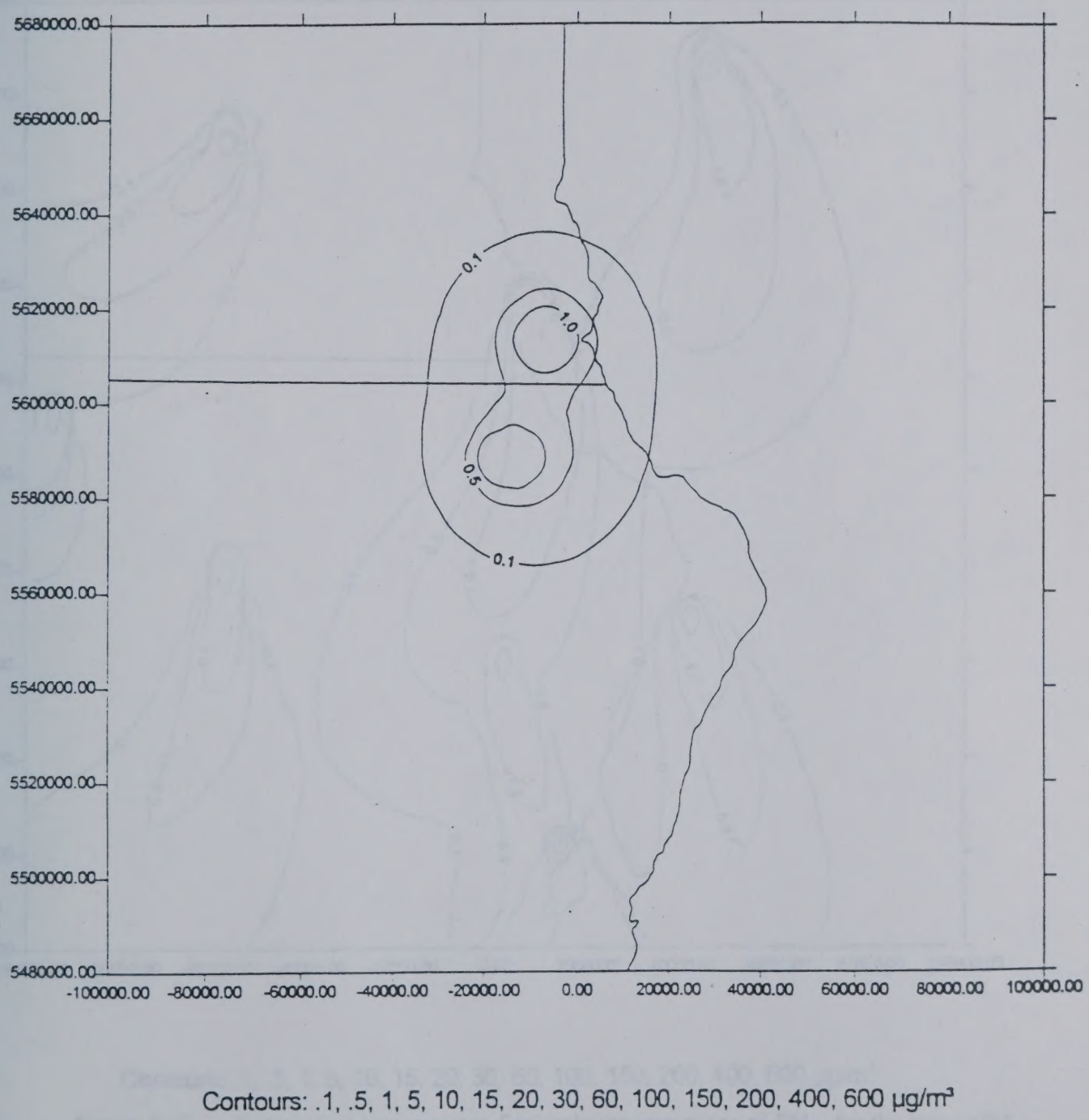
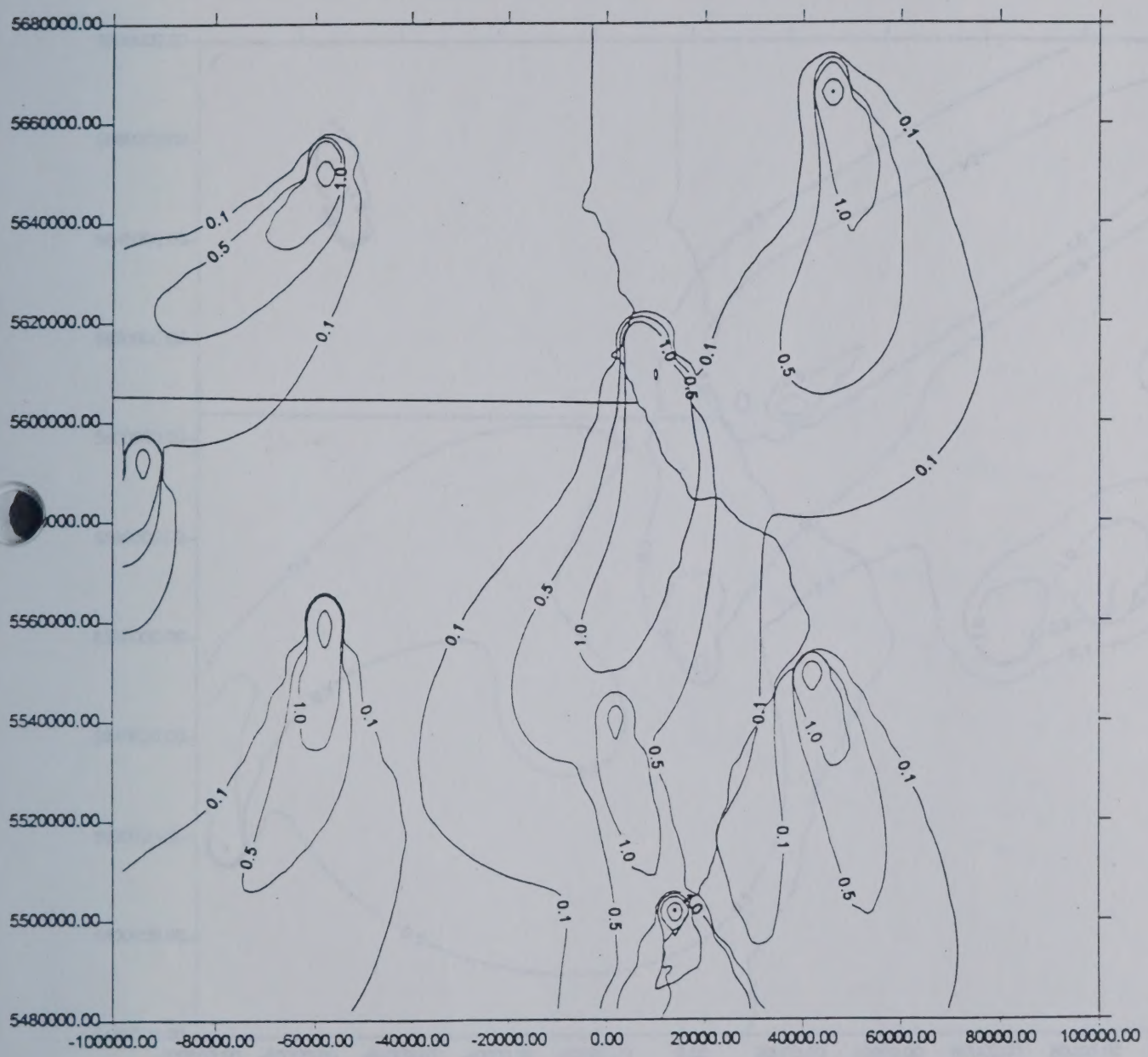


Figure 4-26. Twenty-four hour average fine-scale concentrations of PM_{10} for the early spring prescribed burn scenario (base + 1500%) for March 31, 1990.

US FOREST SERVICE
Base+1500% - Slug Algorithm
24-Hour Averages of PM10
May 4, 1990
Contours in µg/m³



Contours: .1, .5, 1, 5, 10, 15, 20, 30, 60, 100, 150, 200, 400, 600 µg/m³

Figure 4-27. Twenty-four hour average fine-scale concentrations of PM_{10} for the late spring prescribed burn scenario (base + 1500%) for May 4, 1990.

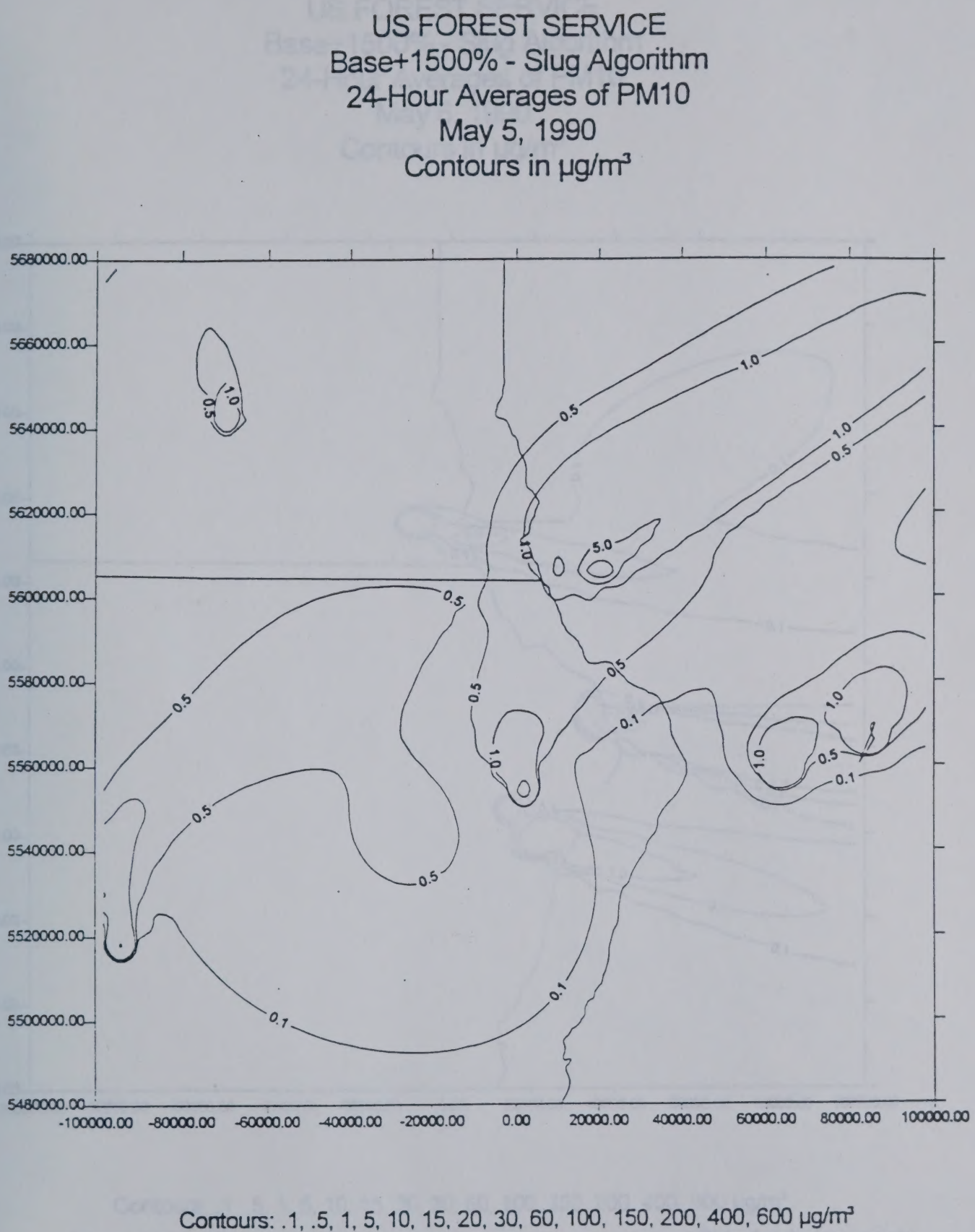
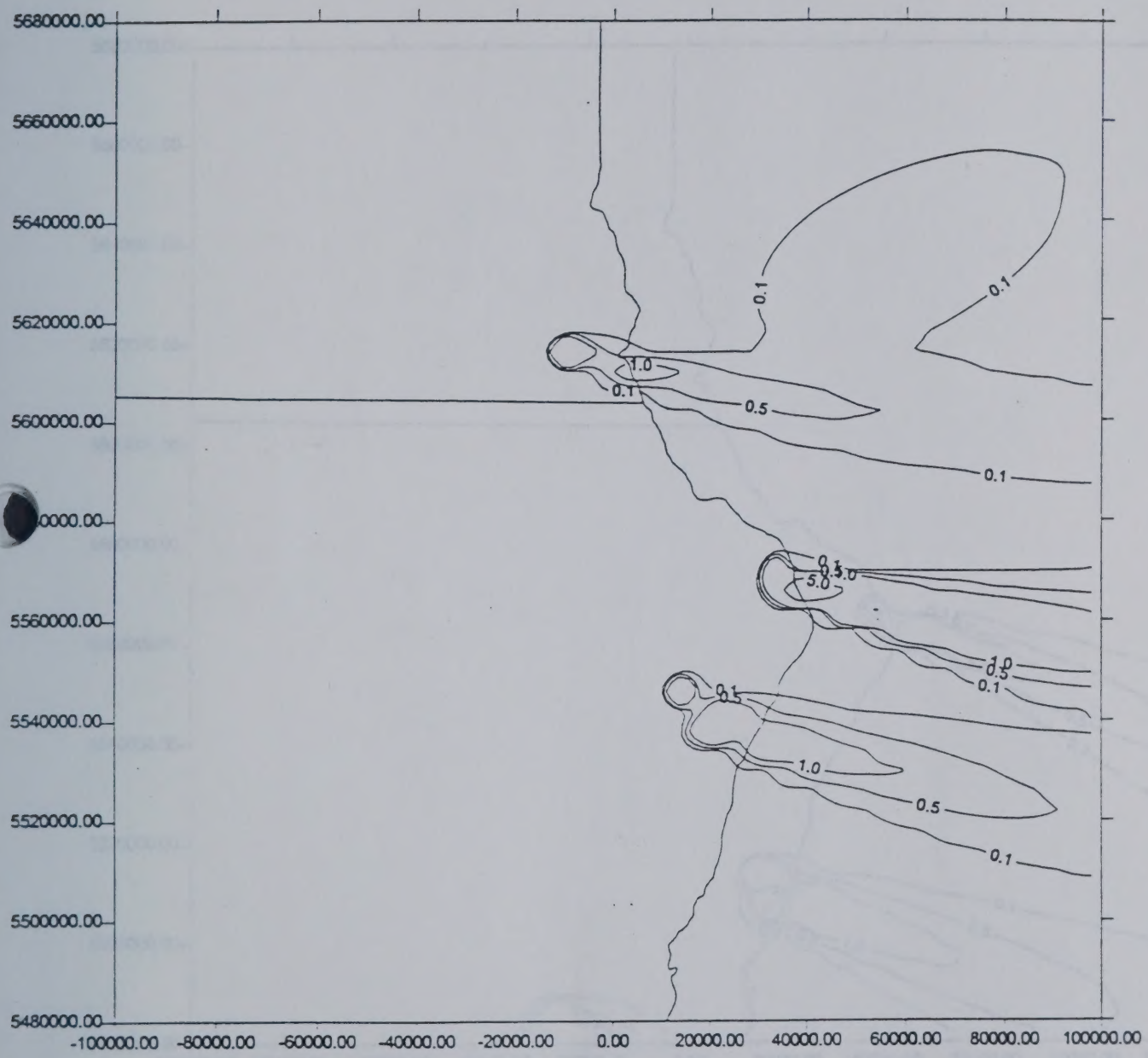


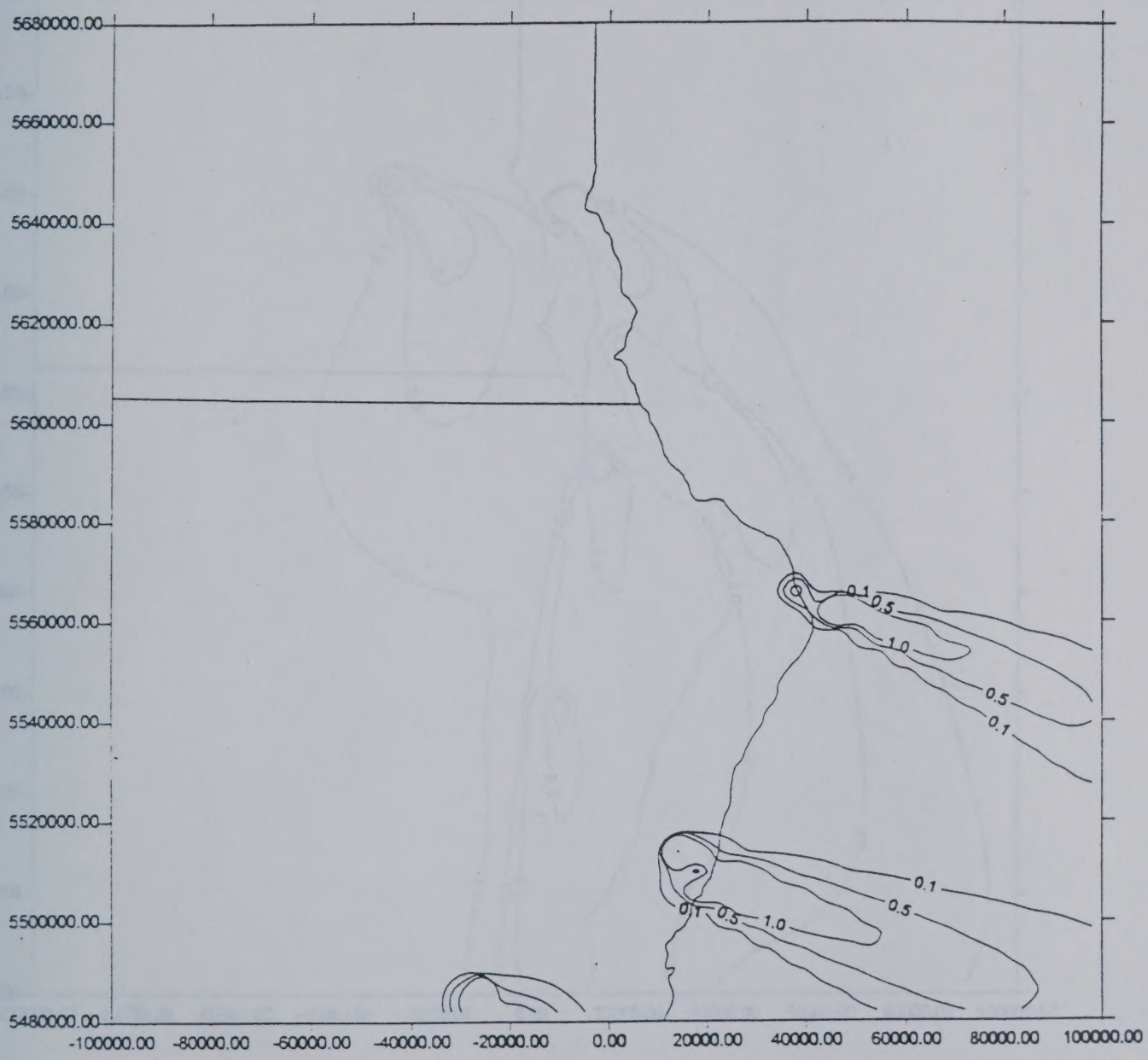
Figure 4-28. Twenty-four hour average fine-scale concentrations of PM_{10} for the late spring prescribed burn scenario (base + 1500%) for May 5, 1990.

US FOREST SERVICE
Base+1500% - Slug Algorithm
24-Hour Averages of PM10
May 6, 1990
Contours in µg/m³



Contours: .1, .5, 1, 5, 10, 15, 20, 30, 60, 100, 150, 200, 400, 600 µg/m³

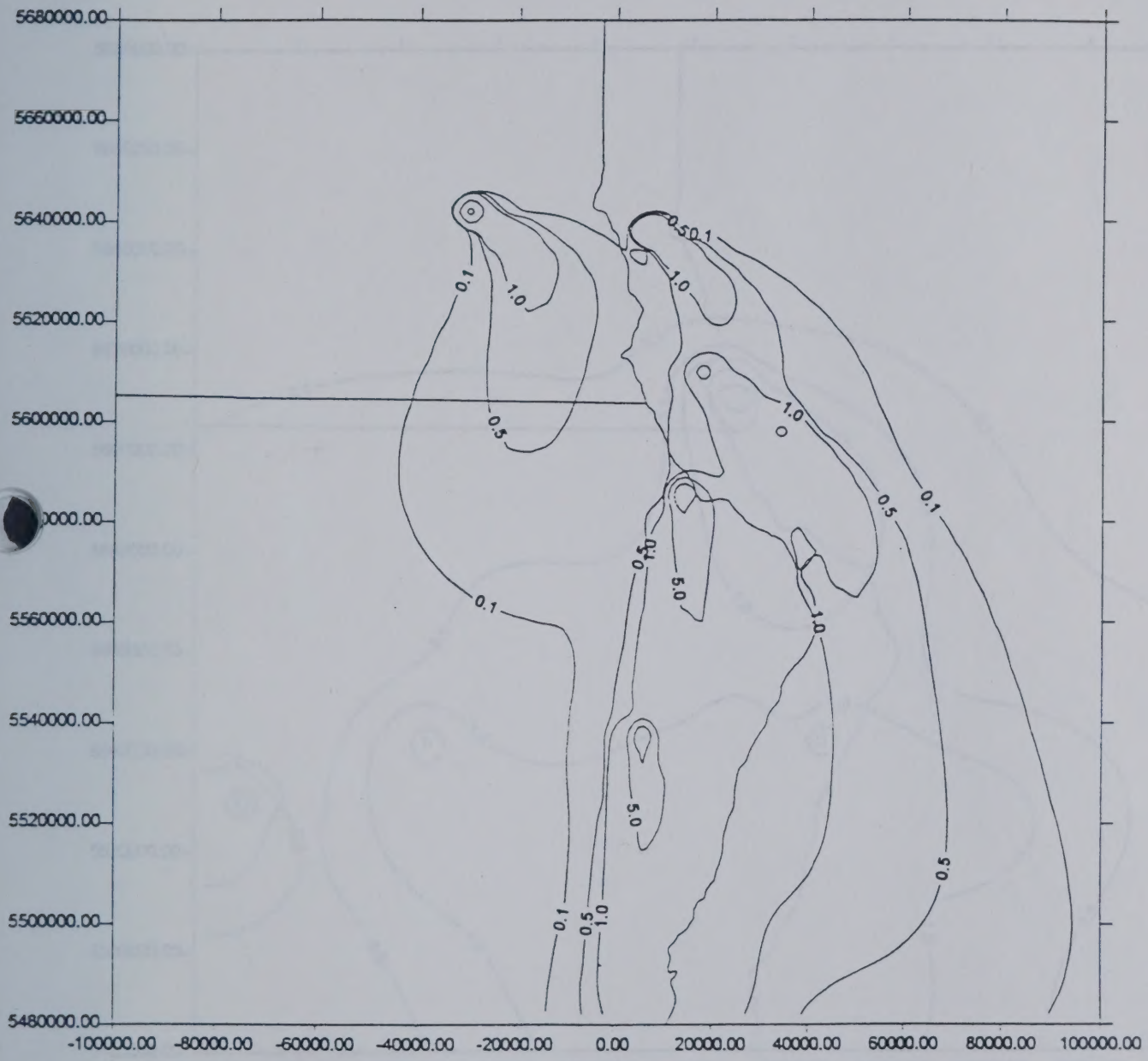
Figure 4-29. Twenty-four hour average fine-scale concentrations of PM_{10} for the late spring prescribed burn scenario (base + 1500%) for May 6, 1990.



Contours: .1, .5, 1, 5, 10, 15, 20, 30, 60, 100, 150, 200, 400, 600 µg/m³

Figure 4-30. Twenty-four hour average fine-scale concentrations of PM_{10} for the late spring prescribed burn scenario (base + 1500%) for May 7, 1990.

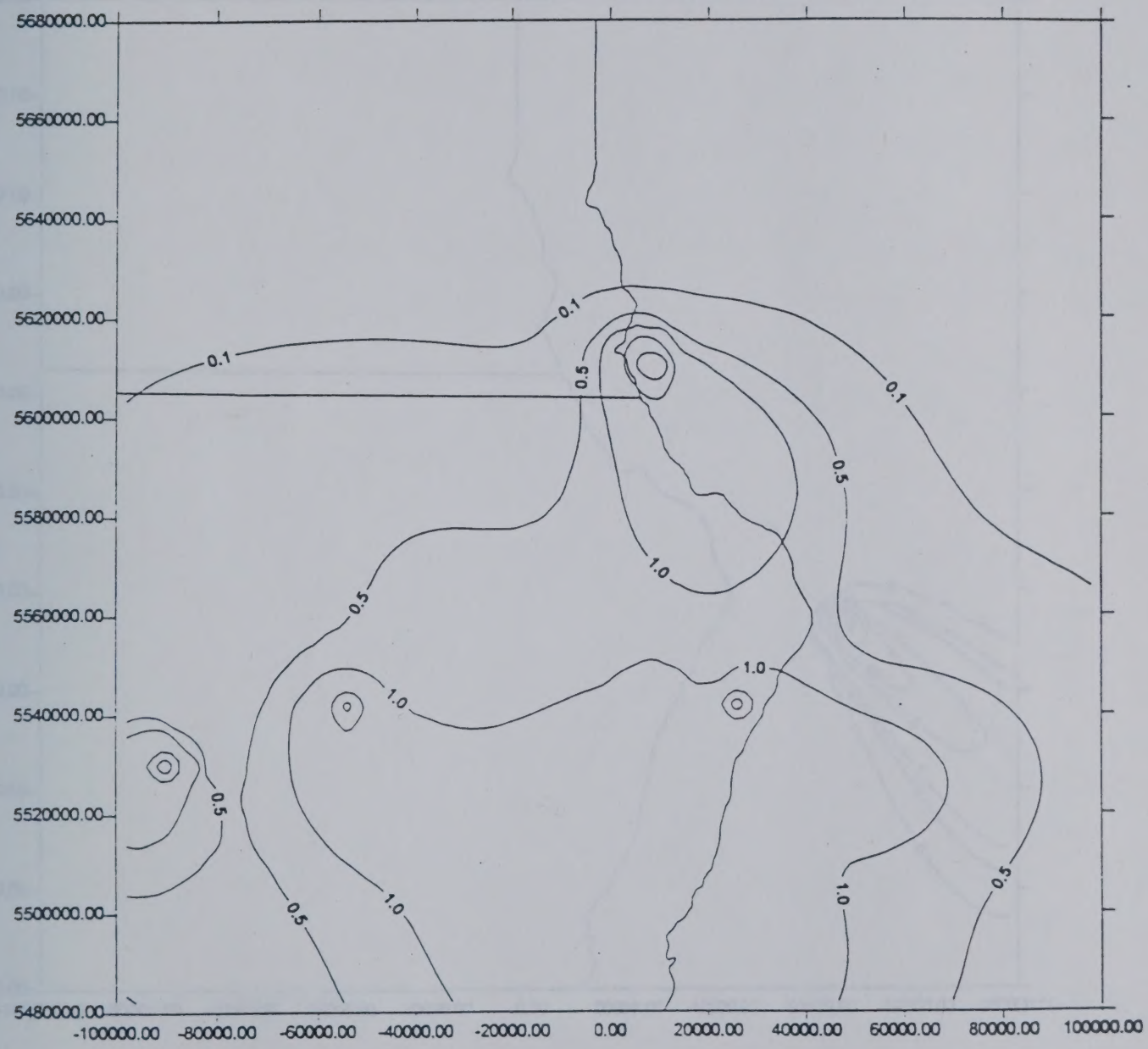
US FOREST SERVICE
Base+1500% - Slug Algorithm
24-Hour Averages of PM10
May 8, 1990
Contours in µg/m³



Contours: .1, .5, 1, 5, 10, 15, 20, 30, 60, 100, 150, 200, 400, 600 µg/m³

Figure 4-31. Twenty-four hour average fine-scale concentrations of PM_{10} for the late spring prescribed burn scenario (base + 1500%) for May 8, 1990.

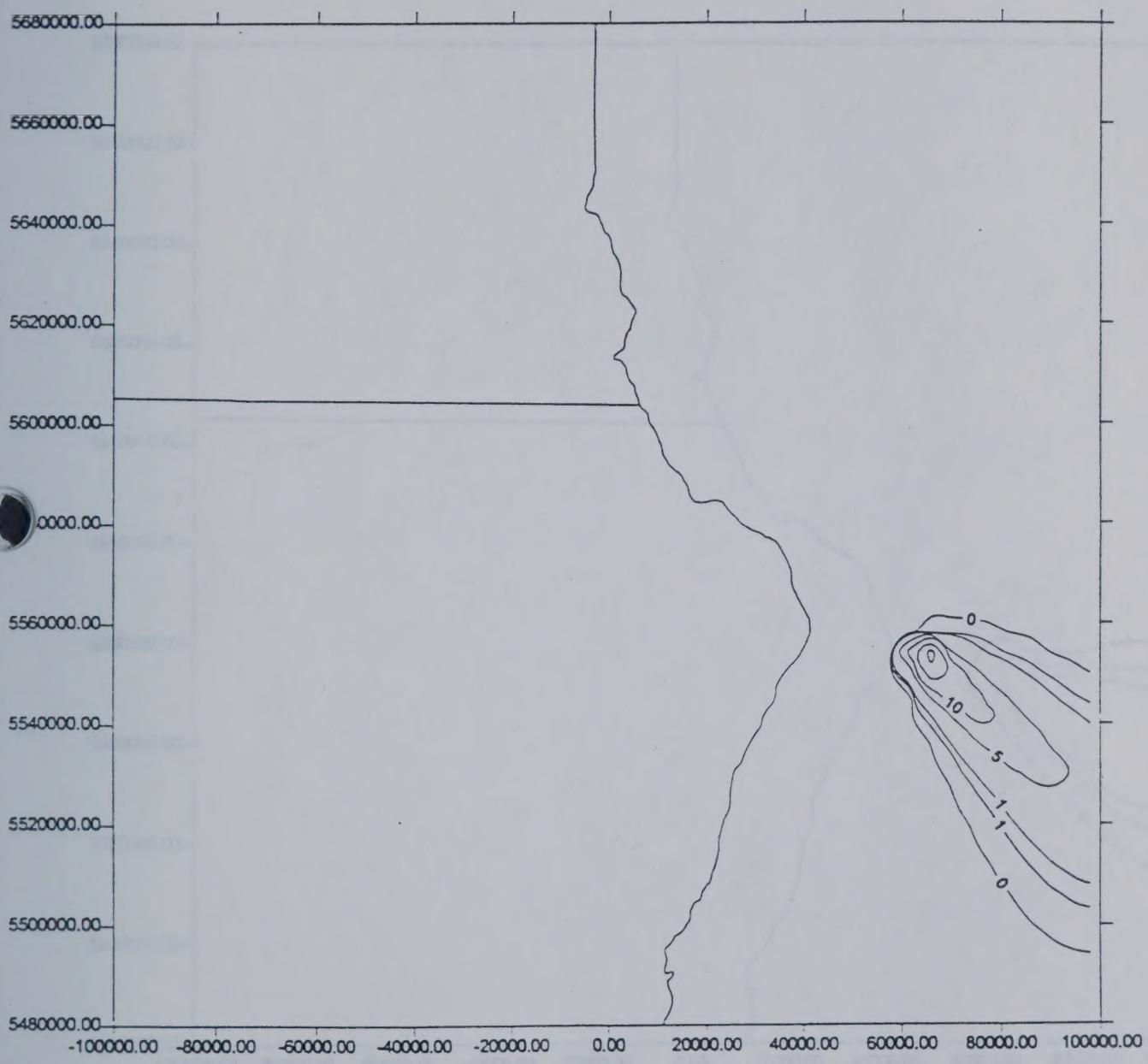
Figure 4-31. Twenty-four hour average fine-scale concentrations of PM_{10} for the late afternoon prescribed burn scenario (base + 150%) for May 8, 1990.



Contours: .1, .5, 1, 5, 10, 15, 20, 30, 60, 100, 150, 200, 400, 600 µg/m³

Figure 4-32. Twenty-four hour average fine-scale concentrations of PM_{10} for the late spring prescribed burn scenario (base + 1500%) for May 9, 1990.

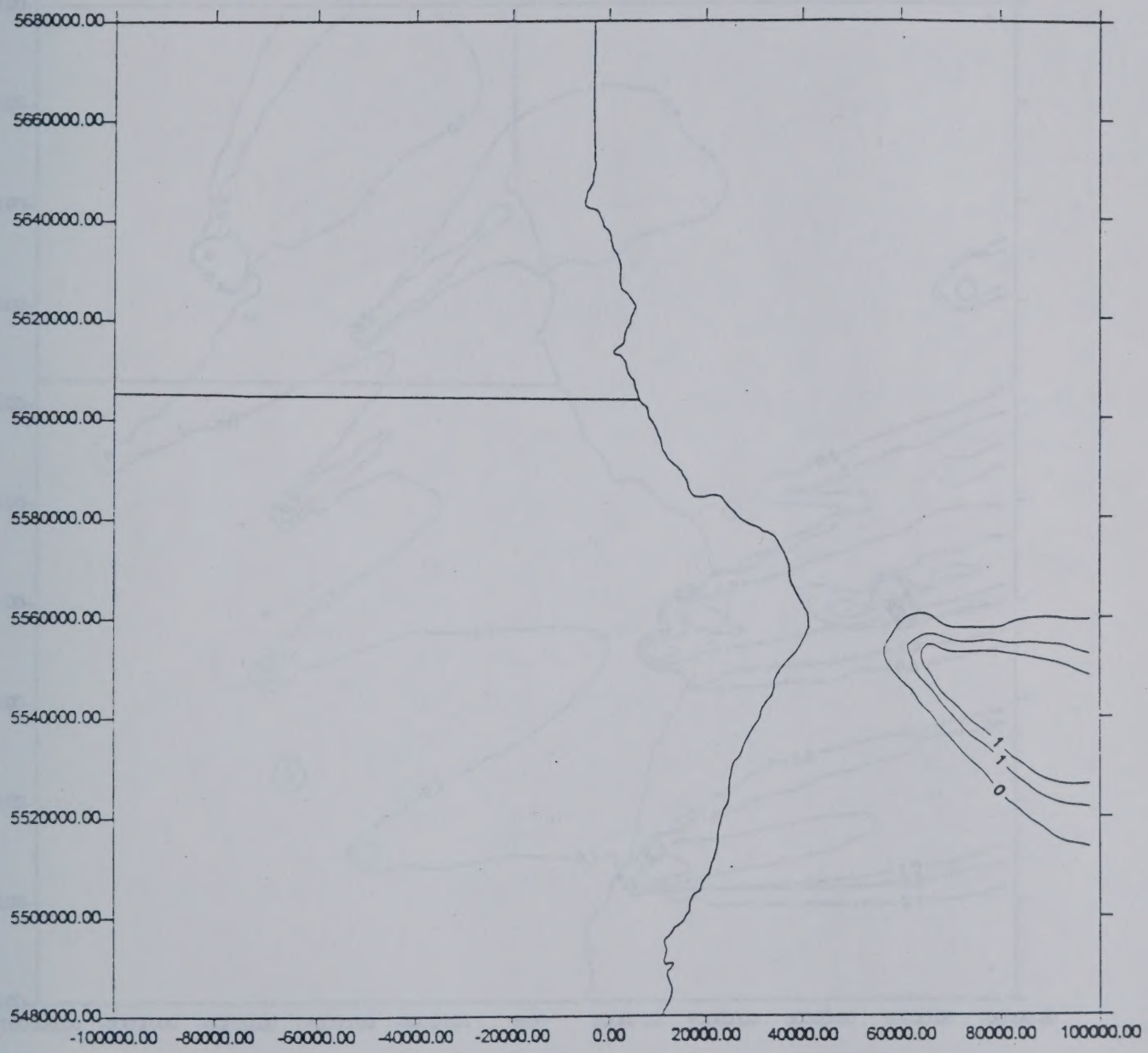
US FOREST SERVICE
100% - Slug Algorithm
24-Hour Averages of PM10
August 6, 1990
Contours in µg/m³



Contours: .1, .5, 1, 5, 10, 15, 20, 30, 60, 100, 150, 200, 400, 600 µg/m³

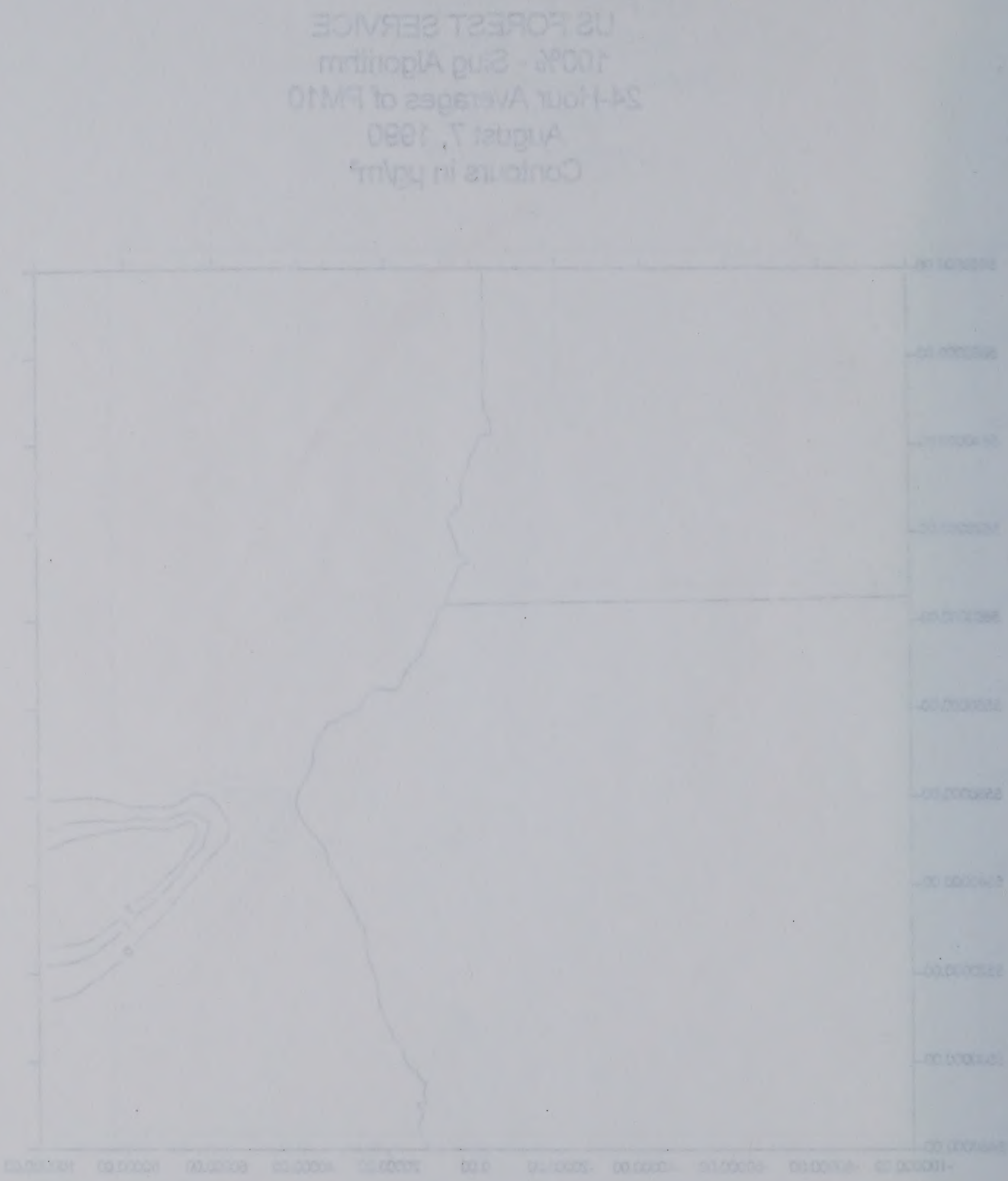
Figure 4-33. Twenty-four hour average fine-scale concentrations of PM_{10} for the summer wildfire episode #1 (100% of base case) for August 6, 1990.

US FOREST SERVICE
100% - Slug Algorithm
24-Hour Averages of PM10
August 7, 1990
Contours in μg/m³

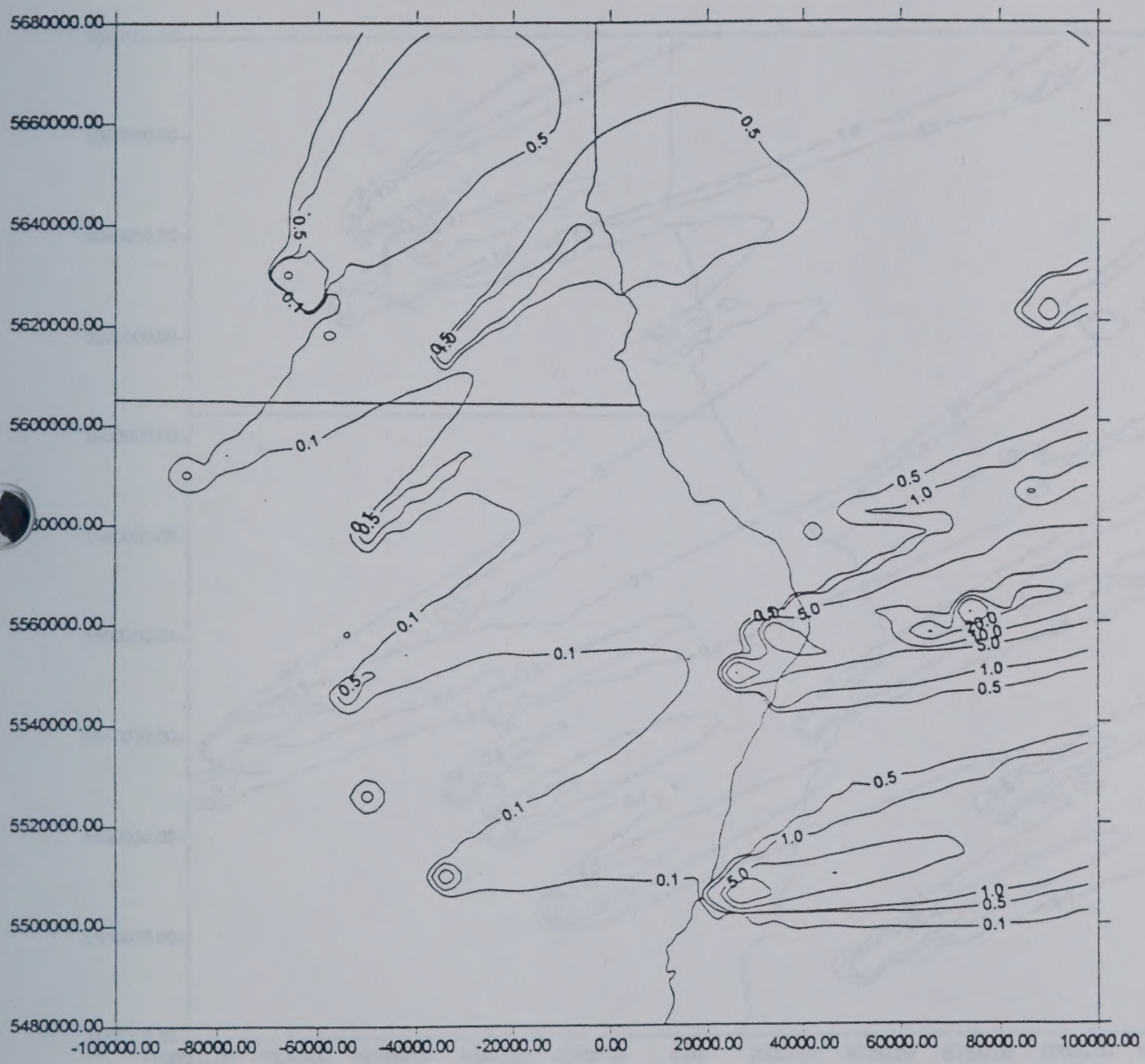


Contours: .1, .5, 1, 5, 10, 15, 20, 30, 60, 100, 150, 200, 400, 600 μg/m³

Figure 4-34. Twenty-four hour average fine-scale concentrations of PM_{10} for the summer wildfire episode #1 (100% of base case) for August 7, 1990.

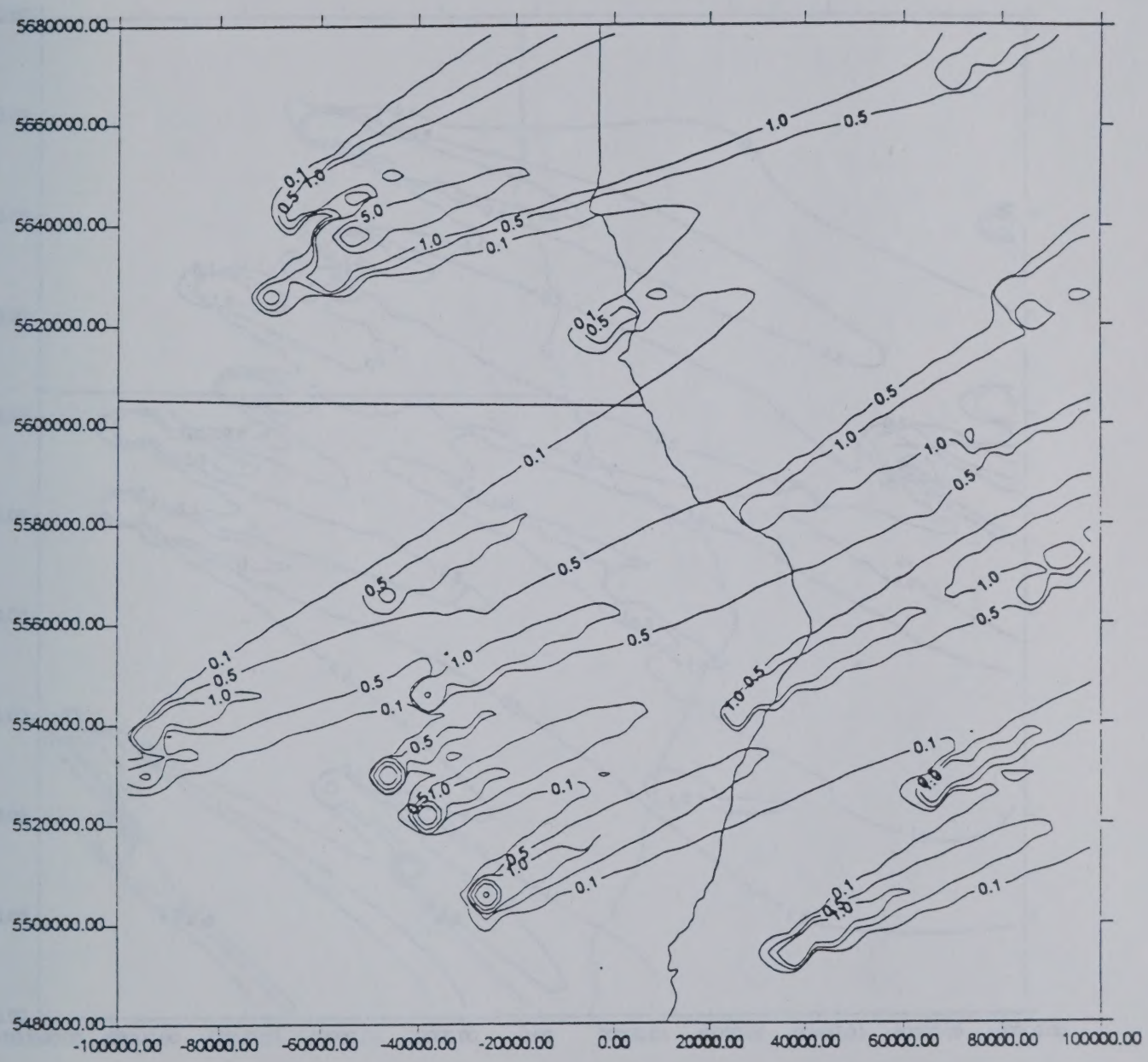


US FOREST SERVICE
Base+1500% - Slug Algorithm
24-Hour Averages of PM10
October 14, 1990
Contours in μg/m³



Contours: .1, .5, 1, 5, 10, 20, 30, 60, 100, 150, 200, 400, 600 μg/m³

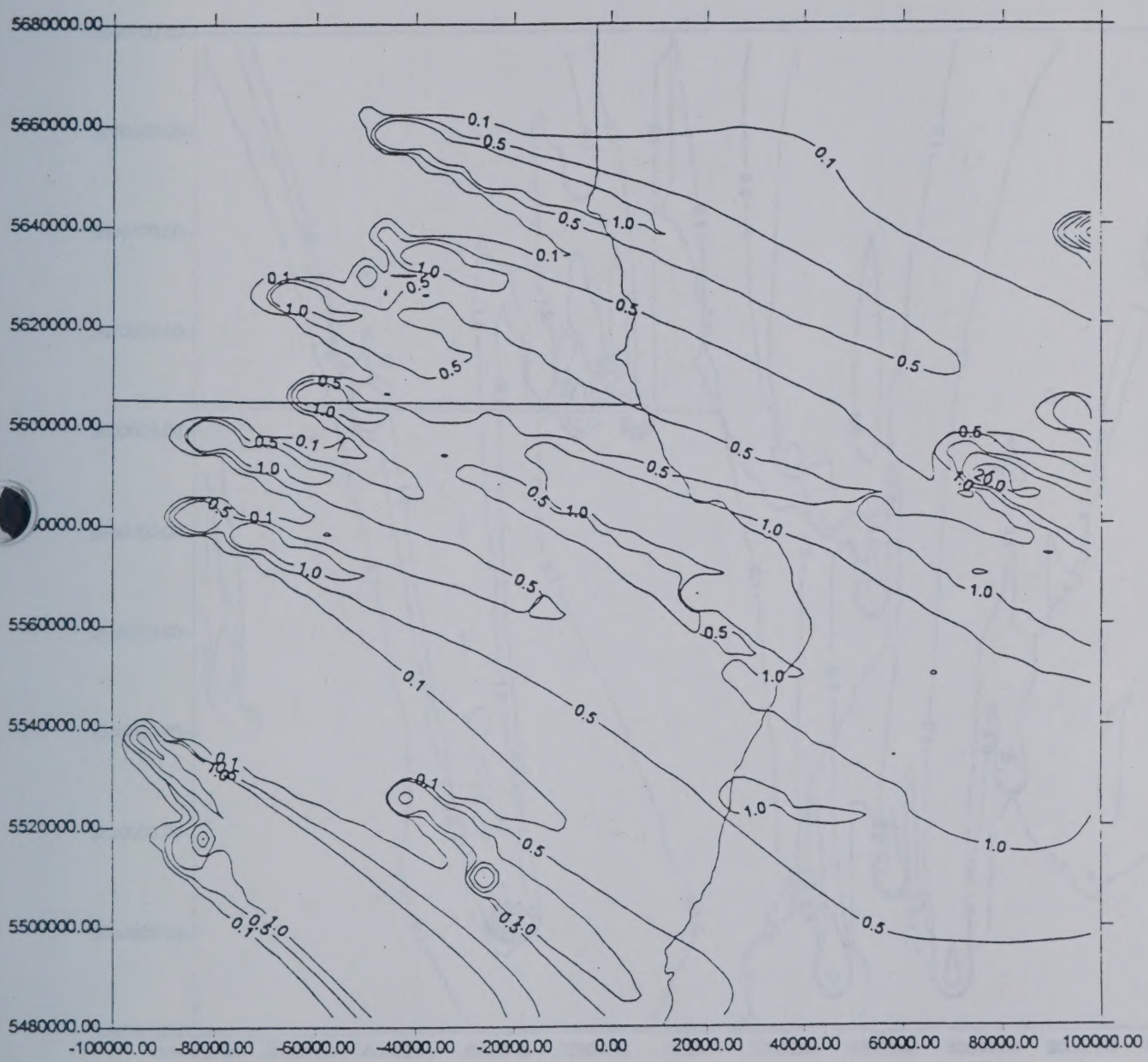
Figure 4-35. Twenty-four hour average fine-scale concentrations of PM_{10} for the fall prescribed burn scenario (base + 1500%) for October 14, 1990.



Contours: .1, .5, 1, 5, 10, 20, 30, 60, 100, 150, 200, 400, 600 µg/m³

Figure 4-36. Twenty-four hour average fine-scale concentrations of PM_{10} for the fall prescribed burn scenario (base +1500%) for October 15, 1990.

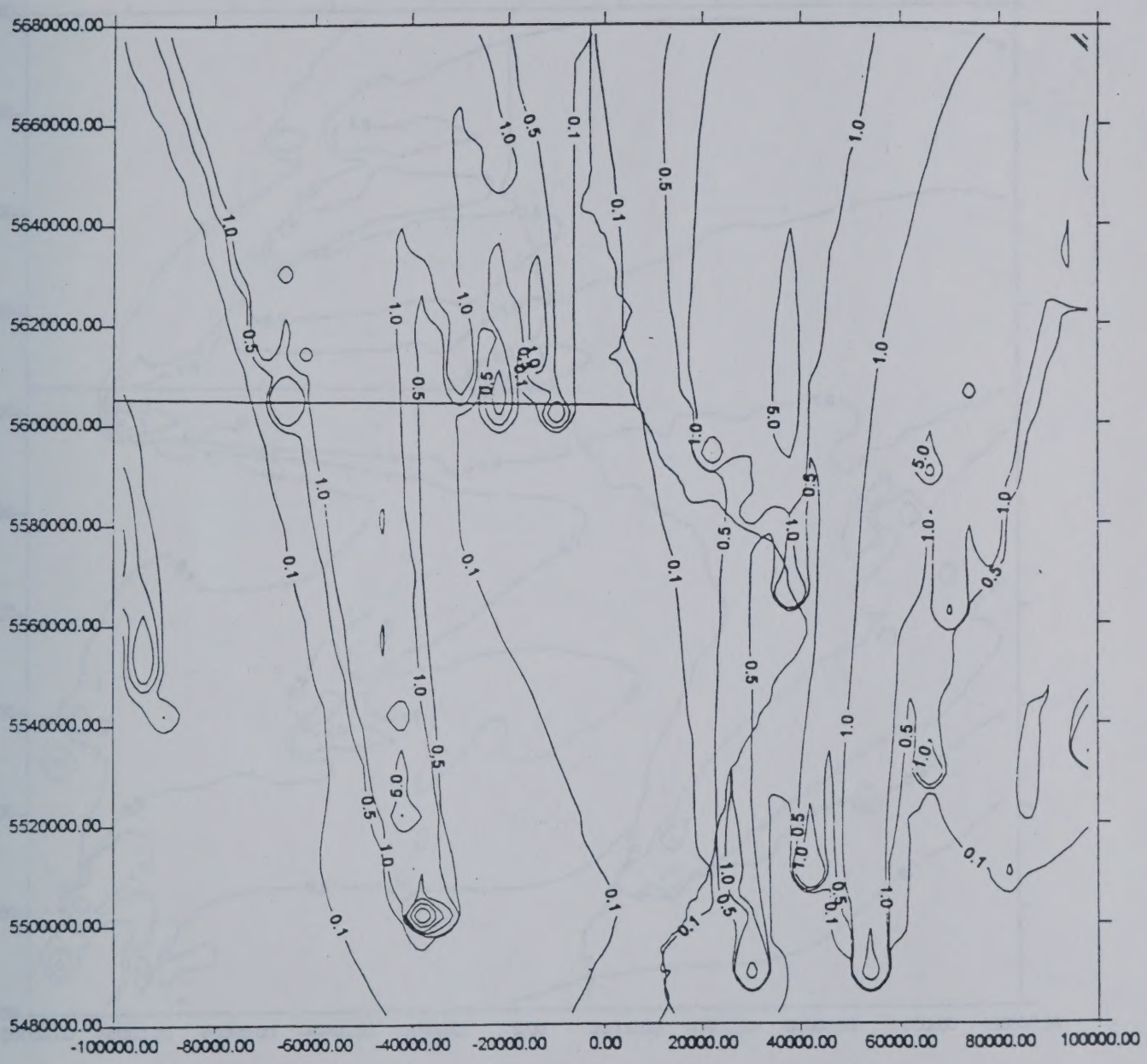
US FOREST SERVICE
Base+1500% - Slug Algorithm
24-Hour Averages of PM10
October 16, 1990
Contours in μg/m³



Contours: .1, .5, 1, 5, 10, 20, 30, 60, 100, 150, 200, 400, 600 μg/m³

Figure 4-37. Twenty-four hour fine-scale average concentrations of PM_{10} for the fall prescribed burn scenario (base +1500%) for October 16, 1990.

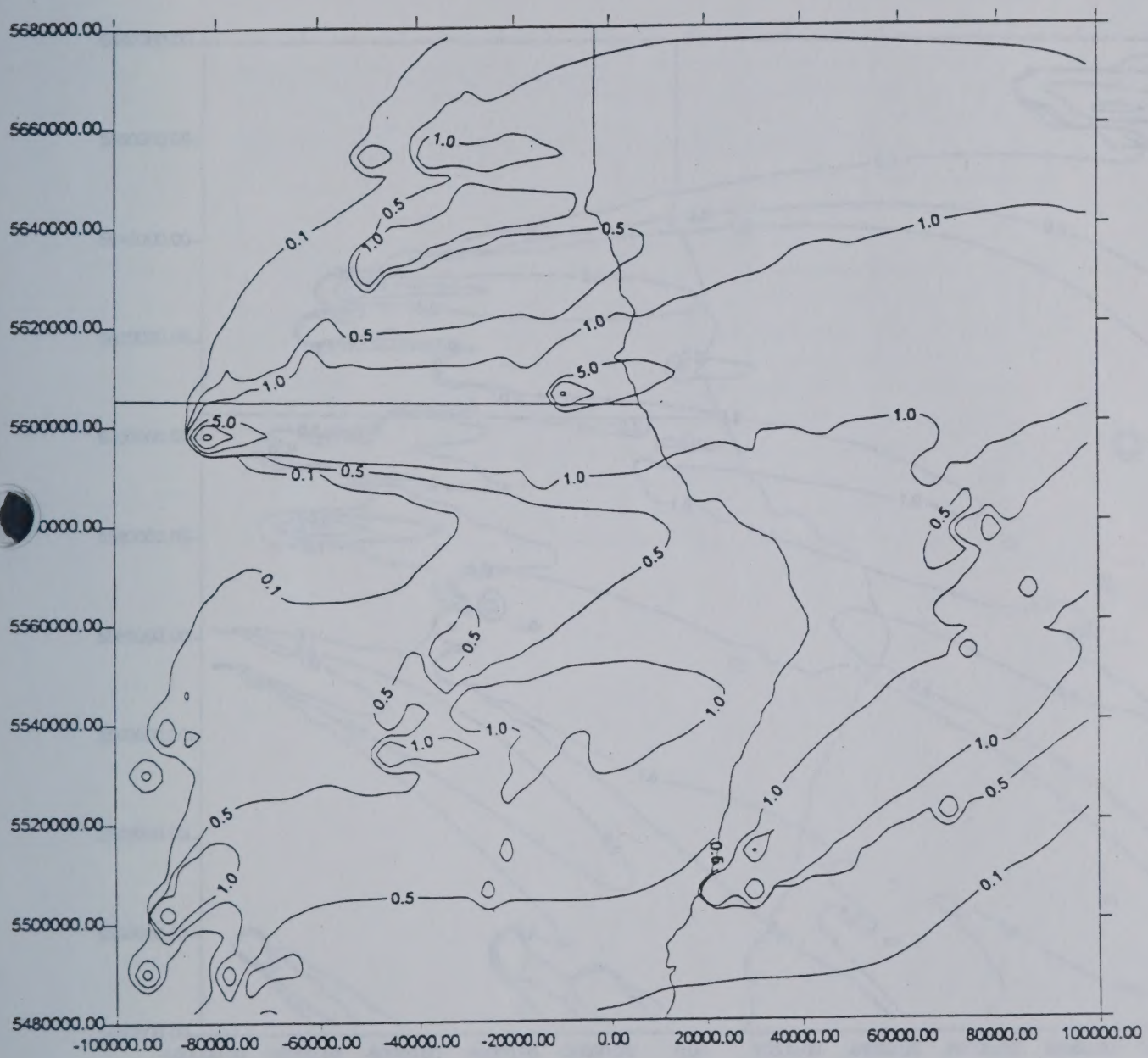
US FOREST SERVICE
Base+1500% - Slug Algorithm
24-Hour Averages of PM10
October 17, 1990
Contours in μg/m³



Contours: .1, .5, 1, 5, 10, 20, 30, 60, 100, 150, 200, 400, 600 μg/m³

Figure 4-38. Twenty-four hour average fine-scale concentrations of PM_{10} for the fall prescribed burn scenario (base +1500%) for October 17, 1990.

US FOREST SERVICE
Base+1500% - Slug Algorithm
24-Hour Averages of PM10
October 18, 1990
Contours in µg/m³

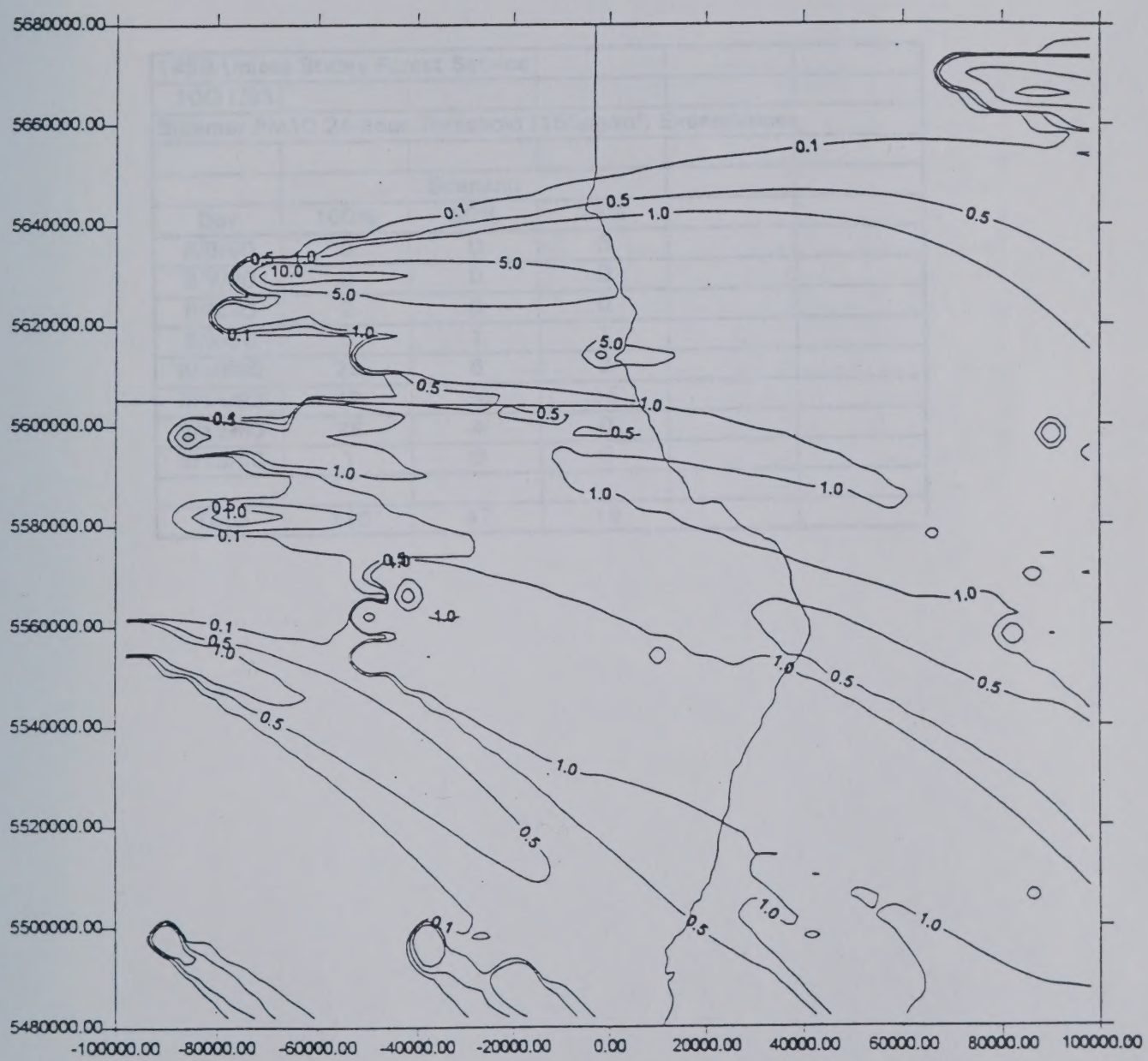


Contours: .1, .5, 1, 5, 10, 20, 30, 60, 100, 150, 200, 400, 600 µg/m³

Figure 4-39. Twenty-four hour fine-scale average concentrations of PM_{10} for the fall prescribed burn scenario (base +1500%) for October 18, 1990.

Figure 4-19. Twenty-four hour fine-scale average concentrations of PM_{10} for the full, preferred base emissions (base + 1500%) for October 18, 1990.

US FOREST SERVICE
Base+1500% - Slug Algorithm
24-Hour Averages of PM10
October 19, 1990
Contours in μg/m³



Contours: .1, .5, 1, 5, 10, 20, 30, 60, 100, 150, 200, 400, 600 μg/m³

Figure 4-40. Twenty-four hour average fine-scale concentrations of PM_{10} for the fall prescribed burn scenario (base +1500%) for October 19, 1990.

Table 4-1

Summer Wildfire Scenario #1

Number of Grid Cells with PM_{10} Concentrations above 150 $\mu g/m^3$

1459 United States Forest Service					
10/31/95					
Summer PM10 24-hour Threshold (150μg/m^3) Exceedances					
	Scenario				
Day	100%	50%	25%		
8/6/90	0	0	0		
8/7/90	0	0	0		
8/8/90	2	0	0		
8/9/90	5	1	1		
8/10/90	25	6	3		
8/11/90	49	36	15		
8/12/90	28	4	0		
8/13/90	1	0	0		
Total	110	47	19		

Table 4-2

Summer Wildfire Scenario #1

Number of Grid Cells with $PM_{2.5}$ Concentrations above 60 $\mu g/m^3$

1459 United States Forest Service					
10/31/95					
Summer PM25 24-hour Threshold (60μg/m^3) Exceedances					
	Scenario				
Day	100%	50%	25%		
8/6/90	0	0	0		
8/7/90	0	0	0		
8/8/90	5	2	1		
8/9/90	41	4	2		
8/10/90	65	24	9		
8/11/90	130	75	42		
8/12/90	157	100	29		
8/13/90	45	2	0		
Total	443	207	83		

Table 4-3

Summer Wildfire Scenario #2

Number of Grid Cells with PM_{10} Concentrations above 150 $\mu g/m^3$

1459 United States Forest Service					
11/27/95					
Summer PM10 24-hour Threshold (150μg/m^3) Exceedances					
Wildfire Scenario #2					
	Scenario				
Day	100%	50%	25%		
8/6/90	1	0	0		
8/7/90	1	0	0		
8/8/90	12	4	0		
8/9/90	55	20	1		
8/10/90	56	16	3		
8/11/90	29	0	0		
8/12/90	26	5	0		
8/13/90	10	0	0		
Total	190	45	4		

Table 4-4
Summer Wildfire Scenario #2
Number of Grid Cells with $PM_{2.5}$ Concentrations above 60 $\mu g/m^3$

1459 United States Forest Service					
11/28/95					
Summer PM25 24-hour Threshold (60μg/m^3) Exceedances					
Wildfire Scenario #2					
	Scenario				
Day	100%	50%	25%		
8/6/90	1	0	0		
8/7/90	1	0	0		
8/8/90	12	4	0		
8/9/90	49	17	1		
8/10/90	40	16	2		
8/11/90	24	0	0		
8/12/90	24	4	0		
8/13/90	9	0	0		
Total	160	41	3		

Table 4-5

Summer Wildfire Scenario #3

Number of Grid Cells with PM_{10} Concentrations above 150 $\mu g/m^3$

1459 United States Forest Service					
11/28/95					
Summer PM10 24-hour Threshold (150μg/m^3) Exceedances					
Wildfire Scenario #3					
	Scenario				
Day	100%	50%	25%		
8/6/90	2	1	1		
8/7/90	8	2	0		
8/8/90	6	1	0		
8/9/90	5	1	0		
8/10/90	25	5	1		
8/11/90	14	1	0		
8/12/90	14	0	0		
8/13/90	7	2	1		
Total	81	13	3		

Table 4-6

Summer Wildfire Scenario #3

Number of Grid Cells with $PM_{2.5}$ Concentrations above 60 $\mu g/m^3$

1459 United States Forest Service					
11/28/95					
Summer PM25 24-hour Threshold (60μg/m^3) Exceedances					
Wildfire Scenario #3					
	Scenario				
Day	100%	50%	25%		
8/6/90	2	1	1		
8/7/90	7	0	0		
8/8/90	3	1	0		
8/9/90	5	0	0		
8/10/90	22	3	1		
8/11/90	10	1	0		
8/12/90	11	0	0		
8/13/90	7	1	1		
Total	67	7	3		

Table 4-7
Number of Grid Cells with Δ dv $\geq$ 1
Early Spring Episode - Regional Domain

Emission Scenario	Mar. 17	Mar. 18	Mar. 29	Mar. 30	Mar. 31
Base	21	17	17	5	12
Base + 100%	21	33	27	16	20
Base + 200%	28	38	59	46	28
Base + 300%	46	42	64	37	44
Base + 500%	46	65	72	42	51
Base + 750%	84	84	112	79	81
Base + 1000%	149	92	147	133	125
Base + 1500%	154	132	183	197	127

Table 4-8
Number of Grid Cells with Δ dv $\geq$ 1
Late Spring Episode - Regional Domain

Emission Scenario	May 4	May 5	May 6	May 7	May 8	May 9	May 10	May 11
Base	11	13	9	12	16	14	13	0
Base + 100%	20	52	22	39	40	23	0	0
Base + 200%	44	61	33	35	50	15	0	0
Base + 300%	56	52	38	68	58	15	9	0
Base + 500%	71	114	72	87	129	26	0	0
Base + 750%	108	112	80	100	107	64	7	0
Base + 1000%	119	138	106	145	218	88	10	0
Base + 1500%	142	249	158	128	210	131	136	0

Table 4-9
Number of Grid Cells with Δ dv $\geq$ 1
Fall Episode - Regional Domain

Emission Scenario	Oct. 14	Oct. 15	Oct. 16	Oct. 17	Oct. 18	Oct. 19
Base	109	40	76	80	64	147
Base + 100%	162	111	158	149	121	231
Base + 200%	295	166	248	224	241	355
Base + 300%	399	320	332	334	312	476
Base + 500%	510	477	612	502	423	623
Base + 750%	707	700	886	751	609	844
Base + 1000%	782	805	1176	941	729	1038
Base + 1500%	792	836	1307	1239	680	1099

Table 4-10
Number of Grid Cells with Δ dv $\geq$ 1
Summer Episodes - Regional Domain

Episode	Emission Scenario	Aug. 6	Aug. 7	Aug. 8	Aug. 9	Aug. 10	Aug. 11	Aug. 12	Aug. 13
#1	25%	9	103	107	281	432	685	910	1061
#1	50%	19	215	242	470	737	1080	1314	1597
#1	100%	26	322	402	757	1077	1541	1900	2238
#2	25%	88	551	636	792	768	1043	1194	1443
#2	50%	104	735	1040	1434	1363	1543	1820	2089
#2	100%	130	914	1327	1859	1807	2092	2305	2570
#3	25%	82	471	767	878	808	979	1186	1468
#3	50%	109	599	976	1177	1075	1294	1723	2155
#3	100%	159	720	1121	1408	1350	1735	2383	2437

Table 4-11

Number of Grid Cells with Δ dv $\geq$ 1

Fine-Scale Grid

Episode	Emission Scenario	Mar. 27	Mar. 28	Mar. 29	Mar. 30	Mar.31			
Early Spring	Base	67	147	74	11	0			
Early Spring	Base +1500%	50	83	92	50	19			
		May 4	May 5	May 6	May 7	May 8	May 9	May 10	May 11
Late Spring	Base	13	63	0	0	0	10	0	0
Late Spring	Base +1500%	467	426	227	155	398	384	0	0
		Oct. 14	Oct. 15	Oct. 16	Oct. 17	Oct. 18	Oct.19		
Fall	Base	52	85	182	104	107	128		
Fall	Base +1500%	261	276	527	832	967	854		
		Aug. 6	Aug. 7	Aug. 8	Aug. 9	Aug. 10	Aug.11	Aug. 12	Aug. 13
Summer #1	25%	21	0	0	0	0	0	0	0
Summer #1	100%	77	0	0	0	0	0	0	0

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